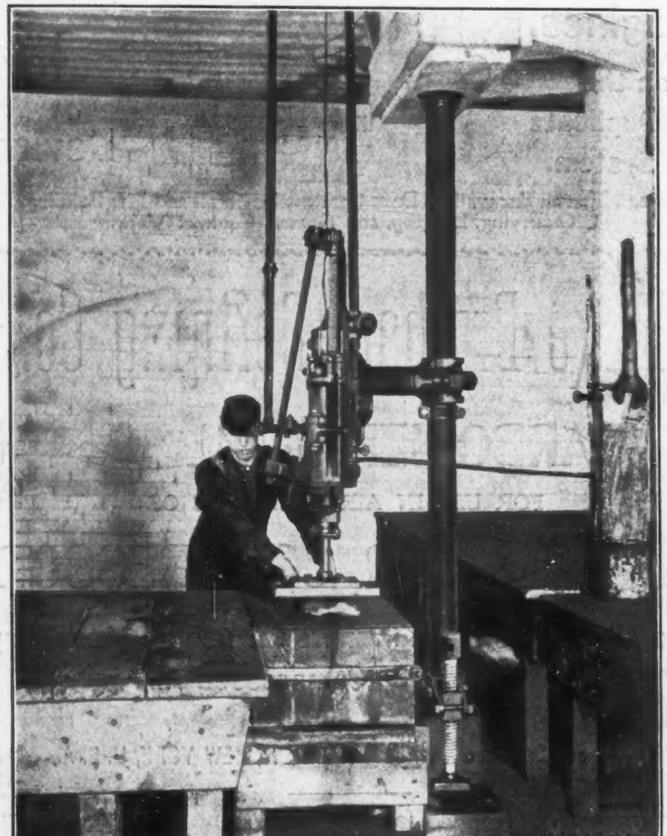
Compressed Air

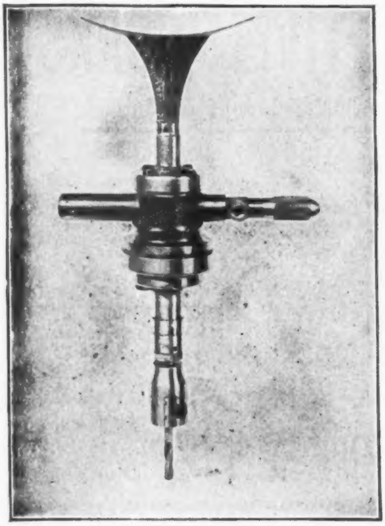
A MONTHLY MAGAZINE DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. V. NEW YORK, JANUARY, 1901. No. 11



"BELLY POUNDER" USED BY MEAT PACKERS AT THE UNION STOCK YARDS, CHICAGO. A ROCK DRILL IS PROVIDED WITH A SPECIAL DIE ON THE END OF THE PISTON AND IS USED FOR TAKING THE "KINKS" OUT OF HOGS' BELLIES AND STRAIGHTENING THEM OUT AS THEY COME TO THE MACHINE IN A FROZEN STATE.

EMPIRE AIR TOOLS.



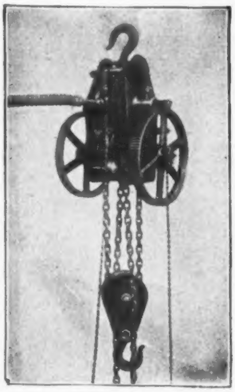
NO. 0 BREAST DRILL.

All Working Parts Incased.
Gears Run in Oil Chamber.

An important feature which is found in NO OTHER pneumatic drill is an oil chamber enclosing the gears and bearings, allowing them to travel in oil, and avoiding wear, friction and frequent oiling.

No. 00 Drill, Capacity 3/16 in. weight 5¼ lbs.
No. 0 Drill, Capacity 7/16 in. weight 10½ lbs.
No. 0 Extra Drill, Capacity ¾ in. weight 15 lbs.
No. 1 Drill, Capacity 1 in. weight 35 lbs.
No. 1 Extra Drill, Capacity 1¼ in. weight 49 lbs.

PNEUMATIC MOTOR HOISTS.



DIFFERENTIAL HOIST.

Take little head-room.
Light, easily handled.
Not dependent on air pressure to sustain load.
Made in following Capacities: Differential, Class "A" Hoists 1,500, 3,000, 5,000 and 10,000 lbs. Friction Brake, Class "B" Hoists, 800, 1,500 and 2,500 lbs.

Our goods are used by the
U. S. GOVERNMENT
in all NAVY YARDS
in the east.

Send for Illustrated Catalog.

FRICTION BRAKE HOIST.

EMPIRE ENGINE & MOTOR CO.,

OFFICE AND WORKS: ORANGEBURGH, N. Y.

Compressed Air.

OR

THE COMPRESSED AIR MAGAZINE.

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

W. L. SAUNDERS, - - Editor and Proprietor
J. E. QUINTERO, M. E. VARIAN, - - - - - - Associates

Subscription, including postage, United States, Canada and Mexico, $1.00 a year. All other countries, $1.50 a year. Single copies, 10 cents.

Advertising rates furnished on application.

We invite correspondence from engineers, contractors, inventors and others interested in compressed air.

All communications should be addressed to COMPRESSED AIR, 26 Cortlandt St., New York.

London Office, 114a Queen Victoria Street.

Those who fail to receive papers promptly will please notify us at once.

Entered as Second-Class Matter at the New York N. Y. Post Office.

VOL. V. JANUARY 1901. NO. 11.

The beginning of the new century seems to be a peculiarly fitting time for us to tell of the status of the compressed air motor in street car service, and it happens that just at the present time we have also at hand data of sufficient interest and authority to warrant us in setting it forth. The readers of Compressed Air have been informed from time to time of the various installations of compressed air for operating street cars. Much of the record has not been of a character to encourage either the participants or the onlookers, and some who were interested and hopeful have dropped out of sight in connection with it. Compressed air seems, when first thought of, so simple in its operation, so easily understood, controlled and manipulated, that it has not received the proper study of its conditions, and in consequence many crude experiments have ended unsatisfactorily. Those who have stuck to it are to be praised for their perseverance, and to be congratulated for the present promise of gratifying and enduring success.

The most interesting installation probably ever yet made of motor cars operated by compressed air is that of the 28th and 29th street crosstown line of the Metropolitan Street Railway Company of New York. It is interesting, especially in the fact that it is a complete installation, no other cars being operated upon the line either night or day but the compressed air cars. In this plant, as elsewhere in compressed air trials, it would seem that the best conditions were not at the first insisted upon. Indeed some mistakes were evidently made. The tracks of this line were cheaply and hastily laid some ten years ago for the light horse cars of that time, with no thought of any heavier traffic, and the track had not been maintained in proper condition, and upon this track the air cars were started. The tracks have since been relaid, and are now in fair condition for the service. We cannot but think also that it was a rash and risky thing to do to start a permanent service of this responsible character with a single unit of supply at the power house. However perfect and adequate the apparatus, there are too many possibilities of accident or derangement for the risk to be taken. The compressor in use is also of much larger capacity than the present service requires, it having been designed in contemplation of partially supplying a much more extensive service, which it was hoped would be and is now confidently expected, will be developed. The compressor is easily capable of supplying three times the number of cars now in service, or three times each day the business of that which it at present supplies. The compressor is now run at 27 revolutions per minute, when it might be run at 75 revolutions. No larger force of men, of course, would be required for the increased speed, although a few more men would be required in the car shed.

The following is an official statement of the running of the present cars since they have been in steady operation. It will be noticed in connection with this statement that the number of cars in operation at the beginning of the period was considerably less than at the last of it. On the day of the Sound Money Parade the running of the cars was stopped entirely by the obstruction of the streets for eight or ten hours.

Record of Air Cars Being Operated on 28th and 29th Sts., N.Y.City.—Round Trip 5.5 Miles.

Date. 1900.	No. of Cars in Opr.	Round Trips.	Total Mlge.	Total Pass. Carried.	
Sept. 26	13	186	1023	13,271	
27	13	215	1182.5	13,724	
28	13	218	1199	13,710	
29	13	222	1221	15,544	
30	13	234	1287	11,840	Sunday.
Oct. 1	13	222	1221	14,474	
2	15	219	1204.5	14,476	
3	15	252	1386	16,253	
4	16	256	1408	16,231	
5	16	270	1485	16,968	
6	16	269	1479.5	17,670	
7	15	239	1314.5	13,240	Sunday.
8	16	269	1479.5	19,069	
9	17	302	1661	18,690	
10	17	302	1661	18,078	
11	17	340	1870	18,599	
12	17	320	1760	18,455	
13	17	332	1826	22,081	
14	18	245	1347.5	12,197	Sunday.
15	18	330	1815	19,520	
16	18	346	1903	21,142	
17	18	340	1870	18,862	
18	18	328	1804	18,692	
19	18	341	1875.5	18,618	
20	18	334	1837	19,672	
21	18	245	1347.5	14,409	Sunday.
22	19	330	1815	19,890	
23	19	324	1782	20,052	
24	19	343	1886.5	20,972	
25	19	354	1947	19,074	
26	19	349	1919.5	19,857	
27	19	356	1958	22,173	
28	18	245	1347.5	12,324	Sunday.
29	19	331	1820.5	19,421	
30	19	335	1842.5	19,341	
31	19	327	1798.5	19,062	
Nov. 1	20	340	1870	19,274	
2	19	345	1897.5	19,978	
3	19	197	1083.5	12,730	Sound Money Parade.
4	16	245	1347.5	13,470	Sunday.
5	20	351	1930.5	19,846	
6	17	256	1408	15,440	Election Day.
7	18	352	1936	21,317	
8	19	334	1837	20,274	
9	19	339	1864.5	19,194	
10	19	341	1875.5	20,035	
11	16	244	1342	12,860	Sunday.
12	20	338	1859	19,525	
13	20	353	1941.5	19,738	
14	20	354	1947	20,056	
15	20	352	1936	19,506	
16	20	352	1936	19,228	
17	20	353	1941.5	22,231	
18	15	245	1347.5	13,454	Sunday.
19	20	348	1914	20,557	
20	20	338	1859	20,300	
21	20	350	1925	20,785	

Total round trips	17,197
Total mileage	94,583.5
Total passengers carried	1,017,269
Average number passengers per trip	59.15
Average number cars running	17.5
Average number daily trips per car	17.2
Average number miles per day per car	94.6

The following is the computed total cost of operating 20 compressed air cars on the 28th and 29th streets (New York) line under present conditions:

	Cents per car mile.
REPAIRS.	
Including material, supervision, and 9 men, adjusting valves, piping, brakes, rods, brasses, labor, etc., $35.00 per day	2.
CHARGING STATION.	
Including oil, waste, foreman, charging gang (2 shifts), oilers, cleaners, etc., $28.00 per day	1.60
POWER HOUSE.	
Including engineers, coal passers, pipe fitter, machinist, oilers, etc., and 16 tons coal per day, oil, waste, etc., $82.50 per day	4.71
Cents per car mile	8.31
Conductors and motormen, inspectors, roadbed, ties and timber, removing snow, salaries of officers, switches, material, etc	9.11
Cents per car mile	17.42

The above computation is made on a basis of 1,750 miles per day, and although every charge is made for the present operating of only 20 cars, yet from 60 to 80 cars could be operated by the charging and power plant without any material increase in cost, so that for a more extensive installation the cost of operating would be materially reduced.

As a reminder to our readers it will be well for us here to recapitulate the principal features of the above installation. The air compressing plant and the shops are at 12th avenue and 24th street. The compressor comprises a 1,000 h.-p. Reynolds-Corliss, vertical, cross-compound, condensing engine with cylinders 32″ and 68″ in diameter and 60″ stroke, running with present load at 27 revolutions per minute under a boiler pressure of 150 pounds, the piston rods of the steam cylinders being extended below into the air cylinders of a four-stage Ingersoll-Sergeant air compressor. The successive diameters of the air cylinders are 46″, 19″, 13.75″ and 6″, with the common stroke of 60″. Effective intercoolers are of course provided between the successive stages and after the final compression. The compressor is designed to compress 3,750 cubic feet of free air per minute to a pressure of 2,500 pounds to the sq. in. Four Babcock & Wilcox boilers of 250 h.-p. each supply all the steam for the compressor and also for the shops and for the hot water service of the motors, which latter is a future essential to their economical operation.

The storage capacity at the station for the compressed air is now 1,050 cubic feet, which can easily be enlarged at will by successive addition of "bottles." Two cars may be charged at once with air and with the hot water for reheating, the entire operation for each car requiring about two minutes. The cars can make two round trips for each charge. They have Pintsch gas lights, the most effective air brakes ever employed and means for heating the cars during the cold season. The cars have each a storage capacity of 55

cubic feet of air at the maximum pressure. Nothing about the car in any way interferes with the passengers any more than in any other car. The operating devices on each platform consist of a reversing lever, throttle lever, air brake lever and a valve for shutting off the air storage. There is a pressure gauge visible, and a hand brake is retained for emergencies.

The cars are 32 feet long over all, the body being 22 feet, and seating 30 persons. The weight of the motor truck is 11,000 pounds and the total weight of the car in running order is 19,000 pounds. The car body is carried on elliptic springs that rest directly on the truck frame and are pivoted by special fulcrum to the car body. The driving wheel axles are journaled in regular locomotive style, and have the usual driving box spring suspension. The cars run steadily and smoothly and there is no jerking in stopping or starting.

The first passage of the air from the storage system of the car is controlled by a valve on the platform. It first passes the reducing valve, beyond which the uniform pressure of 150 pounds is maintained. Before entering the cylinders for work it goes through the hot water tank or reheater. It enters at the bottom by small perforations in a long pipe lying along the top, and thence to the throttle valve. The use of the reheater has been experimentally proved to almost exactly double the efficiency of the air used. The Hardie improved cut-off valve gear secures high economy in the expansive use of the air in the motor cylinders under the wide and sudden variations of load.

The report of the Metropolitan Street Railway Company for the year ending June 30, 1900, gives the relative and actual costs of operating cable, electric and horse railroads. For horse cars the average was 18.98 cents per car mile, the cars being much smaller than those of the other systems; for cable cars, 17.76 cents, and for electric cars, 13.16 cents. The figures were made to include all expenses of operation and maintenance. The estimate given may be assumed to show very nearly the best attainable results by either of the systems at present. The figures given in the computations relating to the air cars evidently do not give the best results, as the conditions are far from being the best that can be secured with our present knowledge. The compressor, as was stated, is very much too large for the present service and works at a constant loss. The plant has all the disadvantages of a new plant in the inexperience and lack of trained judgment of the men employed. It is to be noted that the expenses for repairs, two cents per car mile, are even now remarkably low for any system except the horse-car. On a recent visit to the shops we asked the superintendent what the repairs chiefly consisted in, and he said that there were really no repairs required, what went under that term was the occasional taking up of the brasses and the usual readjustments of the working parts, as with a first-class locomotive. Of the 20 cars, which is the total number on the line, there is seldom more than one at a time undergoing these "repairs." The estimate of the Compressed Air Company that the running expenses can be reduced to 13.57 cents per car mile, when the conditions are all correctly adapted to the work, does not seem to be unreasonable. With this figure crowding so closely the operating expenses of the electric cars it is to be remembered that the air cars have not in addition the enormous fixed charges for the construction of the roadbed which the electric cars labor under, so that with this load added to the electric service the balance is greatly in favor of the air cars.

The most important practical evidence of the favorable light in which the compressed air cars are at present regarded is in the fact that the installation of which we have been speaking was formally taken possession of by the Metropolitan

Street Railway Company on Dec. 13th last, This does not necessarily mean that this system is at once to be adopted in place of the large number of horse cars still running upon the various crosstown and other lines of the city, but that it has at least so far demonstrated its desirability as to make it worth while for the greatest street railway system of the world to undertake for itself to get at the bottom facts in the case. The full service is to be maintained upon the line where it is now in operation, and trials of the Hardin cars are soon to be made upon other lines. Not only the general principles of the system and its general efficiency is to be completely determined, but it is also necessary to know the size of car and the motor and storage capacity best adapted to all conditions. Another car is nearly completed which embodies in every detail of it every improvement which experience has suggested. This car is to have a considerably increased storage capacity, so that it will be capable of running 25 miles upon a single charge of air, and this car will be tried upon any line that may be suggested. The absolute independence of these cars when charged leads to many suggestions of combination routes for them to run on, as with an omnibus system, for the accommodation of the public by quick transit and the avoidance of transfers. Other things being equal, the independence of all connection with the power house and the easy manipulation of the car as long as its charge holds out give the air cars a great advantage, to which is to be added their speed and safety and smoothness of running.

At present it must be said that the compressed air car in New York is commanding respectful consideration. Too much can scarcely be said of the engineering ability and farsightedness of Mr. Robert Hardie, who so long ago so completely designed the present system of operation and of the perseverance both of himself and of Mr. H. D. Cooke, who is still pushing as resolutely and as earnestly as ever.

The "Belly Pounder."

A very novel application of the Steam Rock Drill is shown in the illustration on our cover, and in this form is known among the packing houses as a "Belly Pounder," or, to speak more plainly, it is used in taking the "kinks" out of the hog bellies and straightening them out, as they come to the machine in a frozen state, afterwards being cured and packed in boxes for shipment. The machine shown in the photograph is a modification of the Rock Drill, with the rotating mechanism replaced by a straight guide, forcing the piston to strike a direct, straight blow without rotating. The piston has a specially forged head, to which is bolted a wooden block, or paddle, about 8" x 14" and 2" in thickness. Instead of the usual form of crank on the feed screw, it is replaced by a pair of bevel gears and extension crank, locating the handle convenient to the operator standing on the floor. This permits of the raising or lowering of the machine to accommodate varying thickness of meat. The mounting shown is the regular double screw column, such as is used for mounting the drill in tunnel work, the drill being attached to the arm in the same manner. The cylinder of the machine is 2¾" in diameter, and it can be operated with compressed air as well as steam.

This "Pounder" is now being used by quite a number of the large packers, several of the machines being in operation at the Union Stock Yards, Chicago. The illustration shown was made from a photograph taken at the works of The International Packing Company, Chicago. The saving effected by their use will be appreciated when it is stated that with one of these machines a packer is able to take care of 400 hogs per hour, or to pound 800 bellies in that time. The users report that the work is much better done, requiring less trimming and waste. This, with only two men necessary to the operation of the machine, where they formerly employed six men with paddles to accomplish the same amount of work by hand; a saving in labor of four men. This item alone would in a short time more than pay for the cost of the machine.

Pumping by Compressed Air.

(CONTINUED.)

By E. A. Rix.

Suppose we have six equal-sized tanks, A, B, C, D, E, F (Fig. 8), arranged above each other at distances that we shall shortly determine. Suppose tank A, submerged in a sump and an air pipe conducting compressed air at 90 pounds to this tank. From each tank to the one above there is an air pipe leading from the bottom of the lower tank to the top of the upper one, as shown. From each tank to the one above, there is a water discharge tank leading from the bottom of the lower one to the bottom of the upper one, as shown, and having a check valve on its lower end to keep it full of water. From tank F the discharge is to the surface G. On each tank is a check valve, C, opening the tanks to atmosphere whenever the pressure falls to atmosphere within the tanks, and closing them whenever the water rises against them. Now if tank A be full of water, and air at 90 pounds be admitted, the water will be displaced into the tank B, a distance of 210 feet, just as it did with the Merrill pump, but when the water is all discharged from A, and just before the water discharge pipe is uncovered, the air pipe leading to tank B is uncovered and the air passes up into tank B, expanding against the water and pushing it up into tank C, a distance equal to one-half the absolute pressure of 90 pounds. This must be so, because tanks A and B being equal the pressure becomes 37.5 pounds in both of them when they contain air and not water, so now we have the water in C at 87 feet above B, and in a similar manner it will be pushed into D and E and F and finally out at G, distances 46 feet, 25 feet, 14 and 6 feet, respectively, corresponding to 1/3 and 1/4, 1/5 and 1/6, the absolute pressures of 90 pounds. When F is empty the whole system is full of expanded air at 2.5 pounds, at which pressure it exhausts into the atmosphere. No mechanism is necessary except the one small valve mechanism similar to the Merrill device, and this admits air into A at proper intervals. The rest of the tanks take care of themselves. If fine economy is not required, only the water pipe need connect the tanks; the air pipe may be eliminated and also the check valves in the water pipes, and the air will drive the water from tank to tank and finally escape. The check valves C will then drop open and air may be again admitted at A. The water pipes, being always full, do not form clearance. It matters not how much water is left in the bottom of the tanks so long as they are all alike. That does not form clearance, and, so long as the tank is full before the valve switches, there is practically no clearance. The air as admitted to the tanks is made to bubble up through the water in small bubbles, through a false bottom, and thus the expansion is made isothermal.

The system can be made double, or in any number of units, so that the discharge may be constant. The objection to the system for shaft work is in the space required for the tanks, which might not be objectionable in some places. For outside pumping it would be efficient and easy to install. As to economy, not much of a calculation is necessary to show that if the Merrill pump did 175 foot gallons of work with one cubic foot of free air, at 90 pounds, and lifted the water 210 feet, this system with the same air will do 175x388-210, or 320 foot gallons, because it has lifted the water 87+46+25+14+6 feet, or 178 feet further, or a total of 348 against 210. This makes the efficiency 22x388-210, or 40 per cent., quite an advance over the efficiencies of direct acting pumps.

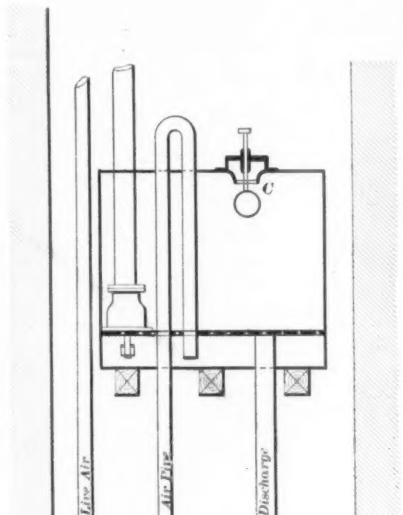
Another peculiarity is that although 90 pounds pressure corresponds to 210 feet head, it is lifting water 388 feet, so that the cylinder ratios, as it were, are inverse.

If we now study diagram Fig. 9, made up from the action of this pump, and allowing that the expansion is isothermal, we have A, B, D, C as the original volume at 90 pounds in the first tank. This expands to E, F, D, I in the second tank, and so on to atmosphere after leaving the sixth tank. It is evident that the triangular areas A, T, E, etc., six in all, are the expansion losses, but when it is considered that these expansions furnish the dynamic head that overcomes the element of time and pipe friction, we see that even if there is loss, it is necessary, and if the air had expanded along the isothermal line we would have been obliged to have added to our initial pressure and quantity to have overcome these resistances, consequently, as a pump, it has a high ef-

ficiency, for it utilizes about all the expansion energy of the air. To calculate it from the card without planimeter, we have as follows:

The card being 7 inches long, 7 atmospheres high and 1 atmosphere to the inch, we have:

M. E. P. isothermal—28.89 pounds.



Multi-Chamber Lift with Expansion.

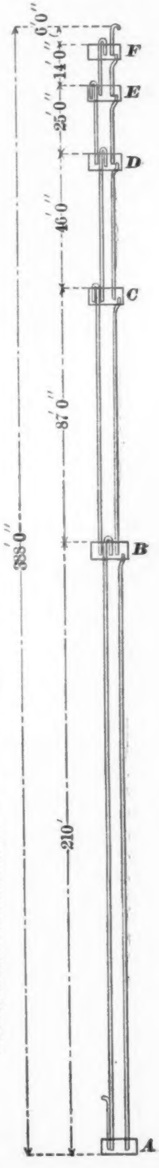


FIG. 8.

We know that Area of Card x Spring-Length=M. E. P.; therefore, M. E. P. x Length-Spring=Area, or, in this case, 28.89x7-15=13.41 square inches.

The card being lined to square inches, it is easy to add up the effective area, and we find it to be 7+7/2+7/3+7/4+7/5+7/6-7x1-.05, the latter being the area R, Q, Y, or 18.15-7.05=11.10 net area. The curve area being 13.41, the efficiency of the pump=11.10-13.41, or 82 per cent., and for the efficiency of the system with simple compression, we have as before, the adiabatic area 18.66, and the work area 11.10 divided by this, gives 59 per cent. efficiency for the system. Allowing for it the same ratio of losses, viz., 7 to 9, as

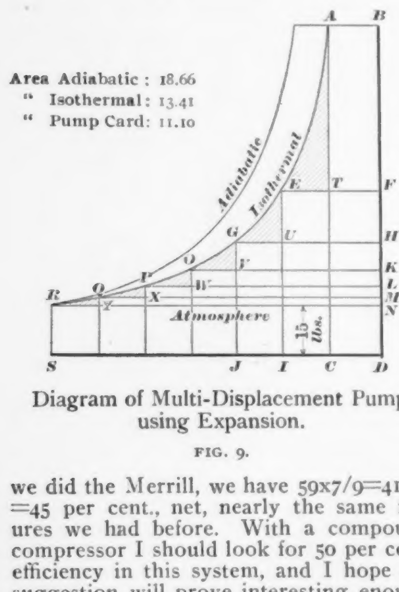


Diagram of Multi-Displacement Pump using Expansion.

FIG. 9.

we did the Merrill, we have 59x7/9=413-9 =45 per cent., net, nearly the same figures we had before. With a compound compressor I should look for 50 per cent. efficiency in this system, and I hope the suggestion will prove interesting enough to encourage some one to try it.

We come now to what I deem the most interesting and useful class of compressed air pumps, viz., the motor displacement pumps, using more or less expansion, otherwise called compound, or multi-cylinder pumps.

COMPOUND OR MULTI-CYLINDER PUMPS.

Judging by results, these are very little understood, even by the people who build them, so far as their use of compressed air is concerned. The general idea has been that if the expansion of air produces such low temperatures that it frequently freezes a simple pump to a stop, it would be an unwise proposition to try further expansion in a compound pump, and consequently the compressed air users have practically avoided multi-cylinder pumps.

I shall hope to show that even a triple or quadruple cylinder pump may be not only operated safely but economically with no further addition of heat than that supplied by the water itself.

Before that, however, I shall speak of the phenomenon of freezing. This is a very simple matter, easily explained and easily prevented. The compressed air being used at full pressure in the pump cylinder, is then exhausted, and, doing its expansion work within and about the exhaust ports, reduces their temperature until ice is formed in the exhaust, which finally closes the opening. I believe the action to be cumulative, and on the same principle used in making liquid air, for I have noticed that when once the pump cylinder becomes quite cold the choking proceeds more rapidly, the idea being that the colder the air previous to exhaust the colder will be the exhaust, which in turn makes the cylinder colder and thus the cumulative action goes on rapidly. I have heard that makers have advised short ports and conically tapered ones, with no threads, to avoid freezing. I have seen pumps with steam injected and pumps with fires under them, and pumps submerged in a tank of water, all to avoid the freezing. Where it is not desirable to reheat pumps with steam or hot air, there are, to my mind, two simple methods of avoiding freezing. First, tap the discharge main with a quarter inch pipe, draw down the end of this pipe until the hole is the size of a knitting needle, introduce this small pipe well into the exhaust of the pump, and let a small amount of water continually discharge therein. It will keep the temperature of the metal above the freezing point, and thus prevent freezing. The loss of water is very small. A pump doing 10 H. P. actual work, and using 250 cubic feet of free air, weighing about 20 pounds, would use, I should judge, about 10 to 12 lbs. of water per minute, or 1½ gallons would be ample for the work. Or, if it is not desirable to waste this water, exhausting through a coil of thin pipe placed in a chamber, through which the suction or discharge

water circulates, will furnish heat enough to the expanding air to prevent freezing.

The second method for preventing freezing would be to use compound pumps, properly arranged. This you will note is exactly contrary to the generally accepted practice. Inasmuch, however, as a compound pump is so different from two simple pumps having the same sizes of cylinders and using the same pressures, and inasmuch as the temperature drop on the initial cylinder is about one-half that of an equivalent simple pump, it is evident that it will not freeze, and if the exhaust be carried through a copper coil over which the water which is being pumped flows freely, the air will become about the same temperature as the water, and it will, thus reheated, pass to the compound cylinder at the same temperature as it entered the initial cylinder, and, passing from this cylinder, it will exhaust without freezing, and the pumping economy will be advanced 30 per cent. or more. Each cylinder would thus dispose of about half the reduction of temperature. If, however, no water heater was introduced between the cylinders, the initial cylinder would discharge the air at a large temperature drop into the second cylinder. This gives a cumulative effect to the cooling at the exhaust of the second cylinder, and rapid freezing up would result. This has led every one to believe compound pumps impracticable for cold air, but by the introduction of the water heated coil between the cylinders, without cost for the heat, the compound pump will not freeze and will be more economical. It is evident that the lower the range of pressures the less the range of temperatures and consequently the less liability to freezing.

To return now to the compound, direct acting pump: Compound pumps of the better class can be given a mechanical efficiency of 70 per cent., which covers the losses in the air and water cylinders and the friction in the pipes, with an allowance for dynamic head. Their economy depends upon the character and amount of the reheating applied to the air.

There are four general classes:

1. Reheating with the water pumped.
2. Extraneous heating before the initial cylinder.
3. Extraneous heating before the compound cylinder.
4. Extraneous heating before both cylinders.

In the first class for mine pumping the temperature of the water may be generally assumed to be 60 degrees, and the heater is a shell filled with copper tubes and preferably made a part of the suction pipes, the water flowing around the tubes through which the air is exhausted from the first cylinder to the second. A steam heater, of the Wainwright type, gives the idea, and about one square foot should be allowed to every five cubic feet of free air. As stated before, its action is to restore the compressed air exhausted from the initial cylinder to normal temperature, thus delivering it to the second cylinder at the same temperature as the first, just reversing the action of the in-

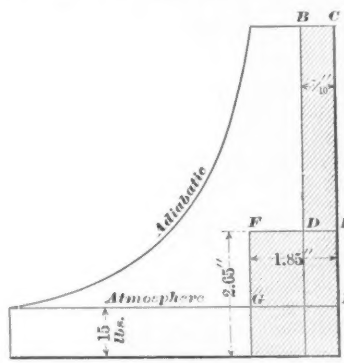


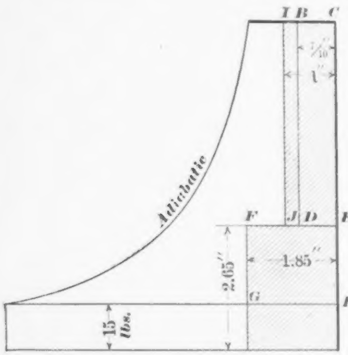
Diagram of Compound Pump, Water Reheated.

FIG. 10.

ter-cooler during compression, and inasmuch as the cylinders use the air at practically full pressure, the expansion takes place in the reheater, and the diagram, Fig. 10, shows what takes place as far as economy is concerned. B, C, E, D is taken at 70 per cent. of the volume furnished to the pump to cover the mechanical efficiency. This expands to 2.65 times its volume (when the initial pressure is 90 lbs.), in the reheater, and F, E, H, G is the volume given the second cylinder. The areas=.7x(7-2.65)=.7x4.35 =3.045+(1.855x1.65)=3.06=6.1 square inches. It will be noted that the work in both cylinders is alike—6.1-18.66=32.7 per cent, against 19 per cent. that we figured by the same method for the simple pump. A very large gain and costing nothing to maintain, the first cost of the

heater being small. I cannot conceive of a more forcible argument in favor of compound pumps.

For compound compression this efficiency will be increased to 37.5 per cent. If our simple pump did 135 foot gallons



Compound Direct-Acting Pump. Reheated to 300° before the Initial Cylinder.

FIG. 11.

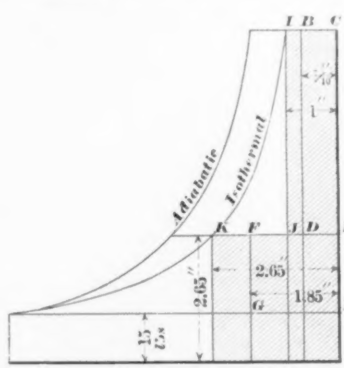
of work, then this style of compound will give 135x32.7-19=232 foot gallons for a cubic foot of free air compressed to 90 lbs. gauge.

In compound pumps where we have extraneous heating previous to the admission of the air into the initial cylinder, let us suppose the heating to be to 300 degrees Fah., this will be sufficient to increase the volume from 7/10 in our former example to 1, in other words, to offset all the mechanical losses in the pump, and the initial cylinder will be full of air at 90 lbs., and at 743 degrees absolute or 283 degrees Fah. When the air is exhausted from this cylinder into the low pressure cylinder there is an expansion ratio of 2.65 between the cylinders, provided there is a small receiver between the two cylinders, the temperature will drop a ratio of 1.32, or, considering the losses by radiation, will reach 60 degrees again and will enter the low pressure cylinder in precisely the same condition that it did in the former case, and with the same volume, consequently we have no gain in this way of reheating, except for the initial cylinder, unless the heating be carried so that the cylinder will receive it at more than 300 degrees, which might not be practicable. In Fig. 11 we have added the area I, B, D, J to our diagram, Fig. 10, and the area of useful work will be 1x4.35+3.06 =7.41, and, the compression area being 18.66, the efficiency is $\frac{7.41}{18.66}$ = 40 per cent., against 32.7 per cent. in the former case, and for compound compression this will be 46 per cent., and the foot gallons of work will be 280 for each cubic foot of free air compressed to 90 lbs. gauge.

If, however, there be a reheating between the two cylinders to about 300 degrees Fah., then the volume entering the low pressure cylinder will be increased about 1.43 per cent., and instead of 1.85 as in Fig. 11, it will become 2.65 and occupy the area shown as K, E, H, L, as per Fig. 12.

The useful area in this card will be 4.35 +4.35=8.70, and it will be noted that the work is the same in both cylinders, and the final efficiency will be $\frac{8.70}{18.66}$ = 46 per cent., and if compound compression is used it will become 53 per cent., and the foot gallons of work which it will perform will be 326.

It will be noted that the points K and I are on the isothermal curve, which means



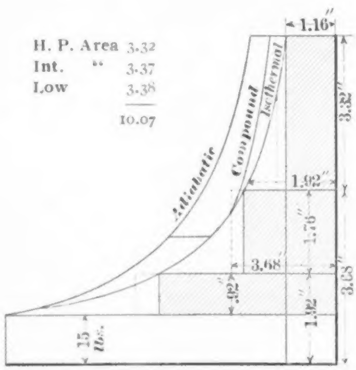
Compound Direct-Acting Pump Reheated to 300° before Initial and Low Pressure Cylinder using Fuel Pressure Only.

FIG. 12.

that we have utilized completely the full pressure work within the isothermal curve, using two expansions, and if three cylinders be used, and proportioned by the same rule, we make a still further

gain and our diagram, Fig. 13, will give 54 per cent. for simple compression and 62 for compound compression, and the foot gallons of work it will perform will be 383, and these figures are perfectly practical and rather under the mark.

It is easy to see that more cylinders would add to the economy, but inasmuch as three are practical and four are too many, we may as well stop here, and for more economy on this system the reheating must be carried higher, and inasmuch as 400 degrees is perfectly practical and as easy to obtain as 300 degrees, this would add 16 per cent. to our percentage of card area, and would give 63 and 72 per cent. respectively, and our foot gallons of work would be 444 foot gallons, and the dotted



3-Cylinder Reheated Compound Pump, using Full Pressure Only.

FIG 13.

lines on the diagram will represent the shape of the card and show how it may extend over the isothermal curve. This I call the practical limit.

In the diagrams shown I have always assumed that the second or third cylinders are so proportioned that there is no increase of pressure by reheating, simply increase of volume.

We have seen that a cubic foot of free air at 90 lbs. pressure will perform, under proper conditions, 444 foot gallons of work. This is 3,685 foot lbs., which may be decreased 5 per cent. as the cost of reheating, making net 3,500 foot lbs. of work. On account of the 70 per cent. efficiency of the compouna pump, we gave it one cubic foot of free air in our circulation and called it 7/10. The air itself must be given credit for this, and if in the 70 per cent. efficiency pump it did 3,500 feet of work it really was yielding up $\frac{3500}{70}$, or 5,000 foot lbs.

It takes 5,600 foot lbs. of work to compress this air in a compound compressor. The air has therefore shown in its work an efficiency of 90 per cent. as a motive power at 90 lbs. pressure, in triple, compound, direct-acting pump cylinders, triple reheated to 300 degrees, a result entirely different from what we are generally almost forced to believe.

Fig. 14 is a copy of a pair of actual cards illustrating the principle of full pressure working. It will be noted that the expansion shown is small, and if the reheater had a little larger capacity the diagram would be rectangular. Unfortunately, at the time these cards were taken, the pump was throttled, and the air was wire-drawing from 70 lbs. to 50, so that its efficiency is diminished. The pump, however, was delivering 396 gallons per minute 390 feet high and consuming 600 cubic feet of free cold air at 50 lbs. pressure, and giving 250 foot gallons per cubic foot of free air, at 50 lbs. pressure, with an efficiency, referred to 50 lbs. of 65 per cent., referred to 70 lbs. of 52 per cent., the total energy from 70 to 50 being lost in the throttling of the pump. It illustrates, however, our proposition and confirms our figures.

I believe that it is the idea in general that the best result in compound pumps using compressed air is to get as much expansion within the cylinders as is possible, and the highest efficiency which could be obtained in this manner would be when there is no drop whatever between the high and low pressure cylinder, and the air is expanded to atmosphere in the low pressure cylinder, as shown by the ideal card, Fig. 15. This would require heating to 454 degrees Fah., the temperature of adiabatic compression.

The practical action of a once reheated compound pump is as follows: The air enters the high pressure cyyinder, we will say, at a temperature of 200 degrees, and at 100 lbs. pressure. This air operates at full pressure throughout the whole stroke, and there is no drop whatever in

its temperature. The exhaust valve opens; there being a considerable space between the high and the low pressure cylinder, in the shape of pipes and clearances, and, if there be an intermediate reheating, in the additional space for the reheater; the pressure immediately drops, we will say, to 50 lbs., and the temperatures suffer in adiabatic proportion to the absolute pressures.

This expansion from 100 to 50 lbs. does no work whatever and is entirely lost. The volume of air shrinks in proportion to the absolute temperature, and then passes into the low pressure cylinder, and immediately commences to expand therein as the piston commences to move. Here will be a case of adiabatic expansion, for the temperature in the cylinder must drop as the pressures drop, and the expansion takes place adiabatically to the end of the stroke, where, with a terminal pressure, we will say, of ten lbs., it drops out into the atmosphere at a temperature probably a few degrees below that of the atmosphere.

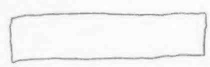
The M. E. P. of the expansion from 50 lbs. down to, say, 10 lbs. is not a very large proportion of the total possible expansion work of the air from 100 lbs. down to 10 lbs., and this is still further reduced by the fact that while we have the expansive work in the low pressure cylinder we have also a variable back pressure on the high pressure cylinder, which means an unequal load on the piston and a consequent variable speed.

An attempt has been made to realize the work of expansion between the two cylinders, but owing to the natural mechanical construction of the pump it is impossible to realize more than a small part of it, and I believe the correct method of operating these pumps is to do all the expanding between the cylinders and restore the volume by reheating, and use only full pressure in the cylinders. We avoid any temperature drops in the cylinders and we have a constant pressure therein and a consequent constant speed and constant back pressure.

In a compound pump the proportion of the low pressure cylinder to the high will then be larger than is in use at present, for the low pressure cylinder will be operated at its terminal pressure throughout the stroke; in other words, the card will be rectangular.

We believe that instead of using two cylinders, with a greater ratio of areas, that it would be better to use three cylinders and proportion the areas between them, so as to have the terminal pressure desired. In this way the drop between the cylinders would be small, and the opportunity to take advantage of double heating would be considerable, and the ideal situation, theoretically speaking, would be where a large number of cylinders would be in operation, one after the other, with only a sufficient drop between them to give them the necessary dynamic head. The combined card would then represent a series of steps considerably

JULY 30, 1900. TEMPERATURES				
Between Heater and Throttle,	248°	Air Gauge,	70 Lbs.	
" Throttle and H. P. Cylinder,	200°	Water Gauge,	160 "	No. 13.
Exhaust H. P.,	78°	Stroke,	14½ Lbs.	W. H. P. H. E.
Inlet L. P.,	289°	Revs. p. m.,	24	Spring 40.
Exhaust L. P.,	134°	H. P. Cylinder,	16 inches.	

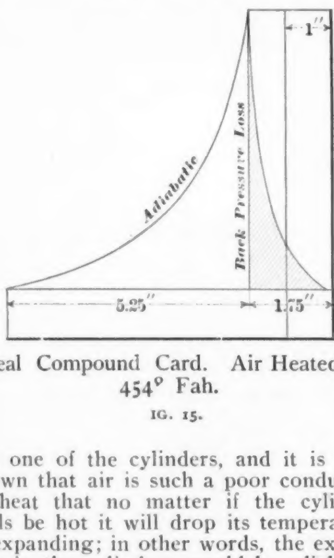


JULY 30, 1900. TEMPERATURES				
Between Heater and Throttle,	229°	Air Gauge,	72 Lbs.	
" Throttle and H. P.,	196°	Water Gauge,	160 "	No. 11.
Exhaust H. P.,	76°	Stroke,	14¼ Lbs.	W. L. P. P. E.
Inlet L. P.,	283°	Revs. p. m.,	23	Spring 16.
Exhaust L. P.,	133°	L. P. Cylinder,	25 inches.	

FIG. 14.

overlapping any possible card that could be made by an adiabatic expansion.

If it were possible ordinarily to expand without drop from the initial pressure, there would be no criticism of ordinary methods, but, inasmuch as a drop must be made, the question naturally arises, is it not better to make the complete drop and take advantage of the situation when the drop occurs and which is neglected when a combination is made of half drop and half expansion? The Comstock offers every possible opportunity for this kind of a proposition. The temperature of the water is 120 degrees, and the pump and the water and the intercoolers and the air and everything will always be at that temperature, except if the air expands in



Ideal Compound Card. Air Heated to 454° Fah.

IG. 15.

any one of the cylinders, and it is well known that air is such a poor conductor of heat that no matter if the cylinder walls be hot it will drop its temperature in expanding; in other words, the expansion in the cylinders would be adiabatic, whereas, if a complete drop is made and the temperature restored between the cylinders, and then it is used in the cylinders at full pressure throughout the stroke, it will approach nearer an isothermal expansion for the air than in any other kind of a practical method with direct acting pumps.

The economical expansion of air must ever be the exact reverse of the economical compression of air, and the ideal air compressor would be one of many stages with a small rise in pressure between each two stages, just sufficient to keep the air moving, and an intercooler to take out the small increment of heat for each stage, making practically rectangular cards between the stages; and the natural reverse of this, for the economical expansion of air, would be a multitude of cylinders with sufficient drop between them to maintain a circulation of the air, and reheaters between each two cylinders, making a practically rectangular card for expansion in each cylinder.

As illustrating the principle which I advocate, attention is called to the diagrams Fig. 16, which are from a compound pump with the air reheated before entering the initial cylinder to 165 degrees Fahrenheit. This pump is doing fair work, raising 450 gallons per minute 424 feet high. It receives air at 63 pounds gauge and 165 degrees Fahrenheit, takes air at practically full stroke, exhausts into the pipe connecting the two cylinders, drops to 35 pounds gauge and gradually expands, as back pressure against the high-pressure piston, until 12 pounds is reached. The low-pressure piston receives the pressure at 27½ pounds and the air is expanded to 11.5 pounds, and it then exhausts against 2 pounds back pressure into the atmosphere.

Assuming the volume of the high pressure cylinder to be one cubic foot, and having no clearance, etc., inasmuch as we are about to make a comparative statement, we find that the foot pounds of work on the high-pressure piston is 6,797 foot pounds, and on the low-pressure piston, 1,581 foot pounds, a total of of 8,378.5 foot pounds.

Now let us consider another method. If we use the air at 63 pounds on the same high-pressure piston and let the exhaust make a complete drop to 11.5 pounds, the work on the high-pressure piston will be 7,416 foot pounds, and if we reheat the air in the receiver to 165 degrees and make the low-pressure cylinder of such a size that after receiving the air at 11½ pounds it will exhaust at 2 pounds, thus preserving the relation of the previous problem, the cylinder ratio will be 3.06 and the work on the low-pressure cylinder becomes 4,186 foot pounds, making a total of 11,602 foot pounds, or a gain of 40 per cent.

Suppose we make it a triple cylinder pump and make each cylinder do the same work and reheat to 165 degrees before the first and between each two, and use the same two pounds back pressure,

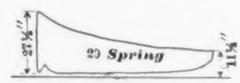
then the initial cylinder will take the pressure at 63 pounds and do 4,550.4 foot pounds, the intermediate will take the pressure at 31 pounds and do 4,450.4 foot pounds of work, and the low-pressure cylinder will take the pressure at 12.4 and do 4,550.4 pounds and exhaust at 2 pounds back pressure, making a total of 13,651 foot pounds, or a gain of 64 per cent. The pump is now doing about 220 foot gallons of work. If we add 64 per cent. to this we will have 360 foot gallons. We claimed 383 in our former diagrams, for higher reheating, which checks results quite nicely. The cylinder ratio in the above will be for equal work in the cylinders, the cube root of the ratio between initial and absolute pressures, 1.7, making the pressure 63 31 and 12.4, respectively. The atmospheric pressure was in this case 13.5 pounds.

heater the deposit of mud on the tubes could be readily detected by noticing the increased air consumption. It is very evident that the more successive air cylinders on a pump, the less drop in pressure will be made from one cylinder to another, and, consequently, less dropping of temperature. It is for this reason that in a multi-cylinder pump water at ordinary temperatures, acting through a number of cylinders, will yield up as many and perhaps more heat units for useful work than a high temperature reheating before the first cylinder. It gives more time for correction, and with air, which is a poor conductor, time is required.

Referring to our last example, using three cylinders, it is evident that if the water was at 60 degrees Fahrenheit the only difference in results would be the increased volume due to the higher temper-

Air 165°

No reheating.



Cards from Compound Pump 14" + 24" Cylinder. Heated to 165° before Initial Cylinder.

FIG. 16.

Your attention is particularly called to the difference between steam and air practice, for here is a triple expansion, so called, operating with 63 pounds initial pressure properly. The number of cylinders that could be properly used would have to be determined by practice, the limit being when their mechanical deficiency offsets their economy.

There are many places where it would be inadvisable to use fire or steam for reheating, on account of heat or annoyance or expense, and it is in such situations that what I term a water reheater will supply enough heat units to render the pumping economical. A general illustration is given in Fig. 16½, which shows how the suction water may, in passing around corrugated copper tubes, render valuable service in heating the air.

In actual practice the difference in the number of revolutions of the compressor to do the same work speaks immediately for the economy of the apparatus. In pumping muddy water through the re-

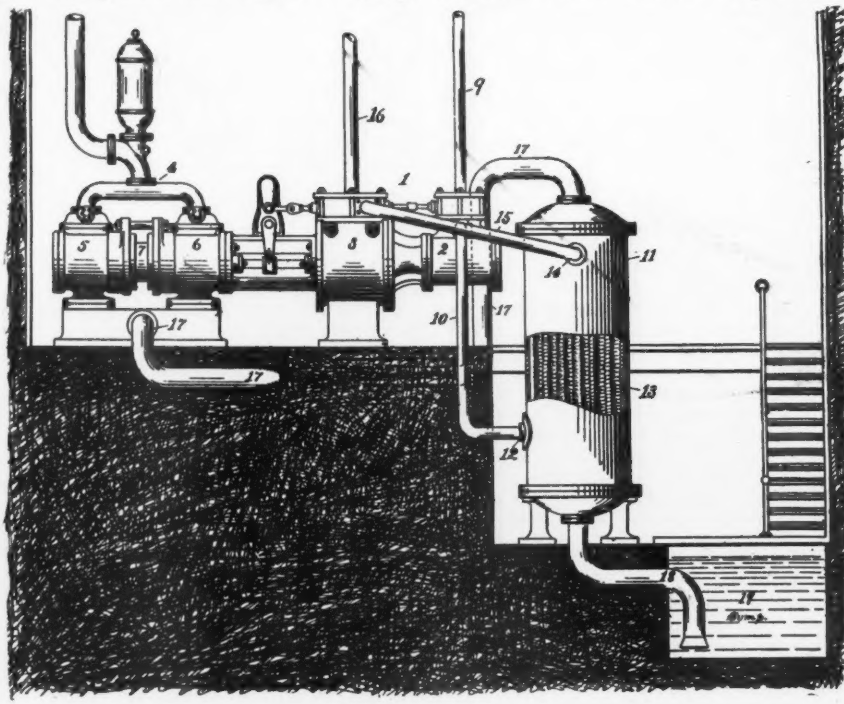
atures. This we counted as 1/5. Deducting, therefore, 20 per cent. from 13,651 foot pounds, we have 10,921 foot pounds, which would be accomplished on the water-heating plan, which is more than was accomplished by heating the initial cylinder of a compound pump to 165 degrees. Please note that this heating costs nothing, and the extra cost of the pump should not be considerable. If by water reheating a triple cylinder pump will do 300 foot gallons per minute, the cost for pumping water would be one-half what it would be in an ordinary direct-acting pump, which power saving would of itself soon pay the cost difference.

COMBINATION OF DISPLACEMENT AND AIR LIFT.

It seems proper under the head of air lift pump to speak of the Wheeler Pneumatic Pump, which is a combination of displacement and air lift, and can be used

in places where there is no proper submersion for the air lift. In fact, the system might be called an air lift system with artificial submersion, shown generally in Fig. 17.

The pump has two displacement chambers and an automatic valve attached, similar to the Merrill pump, and the displacement action takes place similarly, one chamber filling while the other empties, the exhaust being into the atmosphere and the expansive work of the air being lost. The Merrill pump discharges from the chambers directly to the final point of delivery, while the Wheeler pump keeps the discharge pipe filled with water at a certain height, and an air jet at its lower extremity "air-lifts" this water to the final delivery. H. C. Behr, Esq., tested this pump during 1899, and his conclusions in his report are as follows: That the efficiency of the machine, as tested, is such as to compare not unfavorably with the ordinary steam or air driven direct acting pumps of moderate size and as used underground in mines; that the operating expenses could generally be expected to be considerably lower than for such pumps on account of the slight cost for repairs and the replacement of worn parts; that it should require less skill and experience to operate and maintain this pump than a direct acting pump. The efficiencies found might be somewhat increased in cases where a very efficient compressing plant is available. The efficiency will not compare favorably with high-class, air-driven compound pumps reheated. The objection to the pump is that it is not capable of raising the water by suction, and is thus incapable of charging itself. It must be submerged, or the supply must be higher than the water chambers.



Device for Water Heating of Air.—Pat. June 7, 1898.

FIG. 17.

(To be Continued.)

Air Compressor Explosions.*

By Alfred George White.

EXPLOSION IN A COPPER MINE.

The air compressor was employed for the purpose of supplying air to rock drills and hoisting engines in a copper mine in Norway. The usual working pressure being between 50 and 60 pounds, the safety valve of the receiver was loaded to blow off at the latter pressure. It had been continuously at work for seventeen years, and was of English make, with two horizontal air cylinders, 24 inches in diameter and 36 inches stroke. The motive power was supplied by a high-speed turbine on a horizontal shaft, upon which a pinion was keyed, gearing with a spur wheel on the compressor driving shaft. On this shaft also there were keyed a heavy flywheel and two crank disks, which worked the air-cylinder pistons by means of connecting rods in the usual way. The inlet valves were plain circular valves with stems, four being placed in each cover of the air cylinders. Bell-crank levers fitted with counter-weights were attached to the valve stems for closing the valves at the end of each stroke before compression commenced, the atmospheric pressure opening them simultaneously during the inward or inspiration stroke. The outlet valves were of the ball type, of solid brass, fitted in brass seats, two on each delivery port on the top of the cylinders, their action being regulated by the pressure of air in the cylinders and receiver.

The cooling arrangements consisted of an open water jacket round each cylinder, the water supply being admitted near the surface on one side and discharged through an overflow pipe of ¾-inch bore on the other side at the same level. The water surrounded the cylinders and air-delivery ports, and stood about 1 inch deep over the latter. The water supply and discharge being placed at the same level near the top, the water supply flowed over the surface and did not circulate round the cylinder. It will thus be seen how imperfect the cooling action was in this instance.

The oil used in lubricating the air cylinders was composed of crude fish oil and tallow mixed together, and was put into the cylinders through the inlet valves by a common oil can. The lubrication, therefore, depended entirely on the attention and skill of the attendant, and no doubt at times a greater or less quantity of oil was poured into the cylinders than was required, and any surplus was driven out through the delivery valves into the air pipes and receiver.

The air receiver, placed inside the compressor-house, consisted of a wrought-iron cylinder about 20 feet long by 4 feet 6 inches in diameter, and was connected to the air cylinders by an 8-inch cast-iron pipe. This pipe had an ordinary spigot and socket joint on the horizontal portion between the receiver and compressor. The joint was made of lead, run in and caulked, but owing to the contraction and expansion of the pipe it leaked, and had to be renewed from time to time. On the day of the ignition, and shortly before its occurrence, this joint had been renewed by running in molten lead against a hempen gasket, and very soon after the compressor was started, flames blew out in great volume from the safety valve on the air receiver. The attendant succeeded in stopping the compressor within a few seconds, but the flames continued for some time and set fire to the compressor-house, which was built of timber, and in the course of half an hour it was burned to the ground.

WHAT CAUSED THE EXPLOSION.

The author considers the cause which led to the fire breaking out in the receiver to have been the ignition of the oil accumulated there and the use of molten lead in making the spigot joint of the pipe referred to, by which the oil must have been ignited in the pipe. On starting the compressor, the draught of the air created would cause the ignited oil in the pipe to set fire to the oil in the receiver, or the fire may have already spread to the receiver. The products of the decomposition of the large quantity of oil in the receiver would, in conjunction with the air, form an explosive mixture, which, failing relief through the safety valve, might have resulted in an explosion. The cause of all explosions and ignitions of this nature can be traced to these phenomena. The case which occurred at the Westphalia Colliery in 1896, resulted in the destruction of the air receiver by bursting. In the present instance the rise of pressure does not seem to have been sudden enough to burst the receiver, and the relief afforded by the

* Abstract from British Institute Civil Engineers.

safety valve averted this catastrophe. When the receiver was opened it was found to contain a quantity of charred oil in the form of a sticky paste about 2 inches deep in the bottom. The air pipes were coated inside with a similar substance. The damage done to the compressor and receiver was, however, considerable, the riveted joints of the latter being started and the lead joints of the contiguous pipes and connections melted out. One cylinder of the compressor and one crank disk were cracked, as also were two arms of the turbine, which was placed inside the house burned down. The latter effects were chiefly due to the subsequent fire and the water which was thrown upon the heated metal.

The primary cause of the fire was the accidental ignition of the oil by the admission of molten lead into the pipe referred to, but the same effect may be produced by an increase of air pressure, and consequently of temperature, to a point at which the decomposition of the oil and gnition of the air and gas mixtures takes place, or by the admission of coal dust or inflammable matter into the valves or cylinders of the compressor. The use of oils possessing low-flashing temperature from friction of metallic surfaces improperly lubricated is also an element of danger, besides defective water-jacketing and cooling arrangements.

A similar ignition to the one mentioned by the author occurred in 1897 in the Clifton Colliery air receiver, and tests were made of the oil then in use, giving the following results:

	Flashing Point Close Test.	Ignition Point.
Sample No. 1	454° Fahr.	594° Fahr.
Sample No. 2	460° Fahr.	588° Fahr.

Lubricating oils of high-class manufacture, distilled from petroleum and used for high-pressure steam engines, give flashing points of from 530 to 560 degrees Fahr. (open test), and ignition points of from 600 to 630 degrees Fahr. It is, however, sometimes the case that oils having a high flashing point are mixed with others having a much lower one, and therefore a guarantee should be demanded, or a test of the oil should be made. The flashing point of the oil used in the compressor described by the author, taking that of Arctic sperm, would be only 446 degrees Fahr. It is evident that, given reliable oil of high-flashing point and normal conditions of working for a well-designed air compressor, the danger of ignition is practically eliminated.

About two years previous to the ignition described by the author, an explosion occurred in one of the cylinders of the same compressor, resulting in the destruction of the cylinder. The cause of this was not ascertained at the time, but it was probably due either to excessive friction in the cylinder or defective action of the valves, causing an increase of temperature and consequent decomposition of the oil, or to an increase in the air pressure sufficient to burst the cylinder.

Loss of Loads in Air-Pipes.*

STATE OF THE QUESTION.

A great many authors have dealt with the loss of energy sustained by a certain volume of air in its passage through metal pipes; but the coefficients published, correct enough when applied to the pipes experimented with, no longer hold good when extended to those of sheet-iron or tin-plate, and there is great interest in determining the constants to be introduced into the general formula expressing loss of load in the air-pipes used in mines. The author's method of experimenting was suggested by the remarkable labors of M. Murgue, who in the *Bulletin* of the Societe de l'Industrie Minerale, has shown in such a striking manner the influence exerted by the nature of the sides on the resistance opposed to the air's motion through mine workings; and the former's researches, which may be regarded as the complement of M. Murgue's, permit of solving beforehand with sufficient exactitude the problem:

"Calculate the energy necessary to draw through a line of pipes, included in a given circuit, a given volume of air for ventilating the face of a heading;" or inversely, "Given a pipe line of known length, nature and dimensions, forming part of a cir-

*** From a paper by M. Paul Petit, Chief Engineer of the Saint-Etienne Collieries, Loire, France, prepared for the International Congress on Mining and Metallurgy, held in connection with the Paris Exhibition.**

cuit, calculate the air volume that will be drawn to the face by a given power."

MODE OF EXPERIMENTING.

The time-honored formula expressing the loss of load due to the motion of air through pipes is

$$h = a \frac{\mathrm{L}\, p\, v^2}{s}\, \delta,$$

in which a is a coefficient varying with the nature of the sides, L the length of the pipe, p and s the mean perimeter and sectional area, v the mean speed, and δ, the density of the air; and generally the numerical value given to a depends upon a depression (water-gauge), h, expressed in millimetres (say inches) or kilogrammes per square metre (say pounds per square inch) of surface. Finding the value of coefficient a, that characterizes a pipe of known form and dimensions, is connected with a simultaneous determination of the motive depression, h, producing a current of mean speed, v; and the following are the instruments that were used in the author's experiments, with the methods employed for measuring the intensity of the air-current and the loss of load corresponding with a given distance passed through.

Pressure-gauge.—The remarkably correct instrument used by Mr. Murgue, and lent by M. Marsaut, which permits of reading a difference of level correct to within one hundredth part of a millimetre, consists essentially of two glass flasks of very different diameters, connected below by an indiarubber tube. It is only in the small flask that the difference of level due to the diminished pressure is observed, and that with the aid of a microscope, the simultaneous fall of the water level in the large flask not being regarded; and the result of the readings is corrected by calculation. The great sensitiveness of this instrument requires that it be placed on a strong and massive table, for preventing the water-level from being influenced by trepidations; and, for experiments on the surface the pressure-gauge was placed on a thick surface (setting-out) plate, while a portable cast-iron table was made for receiving the instrument in the underground workings.

Anemometers.—For measuring the air volume drawn along by a known depression three small Casartelli anemometers were used, M. Murgue's ingenious method of instantaneously throwing the wheel in and out of gear being adopted.

Atmospheric Observations.—The temperature of the air-current was measured above and below each line of pipes experimented with, or each length of underground road, by thermometers graduated to one-tenth of a Centigrade degree; the pressure being read off from an aneroid barometer; and the humidity in the atmosphere was taken by a very correct hygrometer, the weight of air in motion being calculated by the convenient tables appended to the work by Herr Althans, president of the Prussian sub-committee on ventilators.

Air-pipes.—In the first series of experiments sheet-iron pipes of 27 mm. (1 1-16 in.) inside diameter with screw socket connections were used; but, owing to their joints not being found tight notwithstanding every precaution, lead pipes of 17 mm. (21-32 in.) inside diameter and 3 mm. (⅛ in.) thick, soldered together if necessary, were used for the second series—that metal, which affords absolute tightness,

FIG. 1.

being suitable on the surface where these experiments were made, although its softness would be an objection under ground.

Production of the Air-current.—The various lines of pipes experimented with were in turn laid out in the yard of the workshops, near the boilers; and an exhausting fan at the down-stream end set up an air-current, the intensity of which could be varied at pleasure. For straight lines of pipes a Rateau fan of 70 cm. (2 ft. 3 in.) diameter, driven directly, was used; but in subsequent experiments, for obtaining more intense currents, and consequently greater difference of pressure than could be more correctly measured by the gauge, a Mortier diametral fan of 90 cm. (2 ft. 11 in.) diameter and the same width, also driven directly, was utilized. The trials with curved lines of elliptic pipes and those of large diameter were made in the locomotive running-shed, an arrangement which permitted of the experiments being continued uninterruptedly in all weathers.

Measuring the Air-current—The annexed diagram, fig. 1, shows the general arrangement adopted, in which the pipe, C D, to be experimented with is inserted between two adjutages, B C and D E, the former receiving the air-current drawn in by the fan through a convergent inlet-piece, A B, while the latter delivers it to the exit-piece, E F, also convergent, connected with the fan inlet, G. The adjutages, and also the inlet and the outlet, are made of ploughed and tongued boards, carefully fitted; and the air volume was measured near the inlet and outlet in the cross-sectional plane of their adjutages. The gauging station was placed at such a distance from the inlet and outlet of pipe C D that the flow might be considered as taking place by parallel currents, uninfluenced by the contraction due to the air's motion, between the larger sectional area of the adjutage and the more or less reduced sectional area of the pipe experimented with. By simultaneously measuring, in the entrance and exit adjutages, the air volume passing at each of the stations, it was possible to estimate the quantity of air infiltration and check the degree of tightness in the whole arrangement.

In all the series of experiments the sectional area of the adjutage D E remained practically constant; and the inlet with its adjutage was adapted to the size of the pipe to be experimented with. As the energy that could be set up by the fan was limited, it became necessary, for measuring the volumes of relatively slight intensity circulating through pipes of small diameter, to reduce the sectional area of the inlet adjutage to the value corresponding with a speed of current that could be exactly measured by the anemometer. The connection of the various pipes with the entrance and exit adjutages required great care, for avoiding the infiltration of air that might escape being registered by the anemometer, and thus falsify the measurements of the volume; and on that account the pipes were allowed to project slightly inside each adjutage so as to bear against partitions, carefully constructed of thick boards ploughed and tongued, forming part of the adjutage, luted with putty and having an aperture of the same diameter as the pipe.

For measuring by the anemometer the intensity of an air-current passing through pipes so small as those experimented with, a difficulty arose that does not present itself in the gauging of mine workings; and it is evident that the dimensions of the entrance adjutage cannot be too much increased without a risk of excessively diminishing the speed of a weak air-current. Now, for a moderate section of adjutage the presence of an experimenter may greatly invalidate the observations; and it would become impossible to simultaneously measure the air volume passing through the pipe and the depression of the current. For getting over this difficulty, the following arrangement, due to Herr Althans, was adopted:

Referring to fig. 2, the rectangular sectional area of the gauging station was

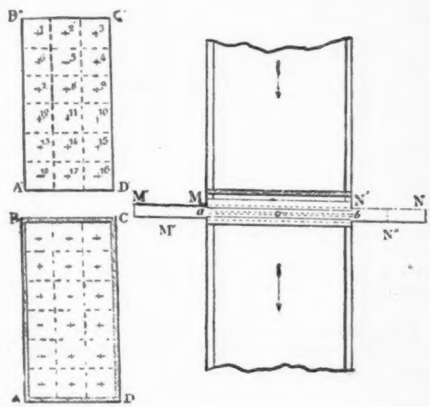


FIG. 2.

represented full size by a tablet, A′ B′ C′ D′ placed above the adjutage, A B C D, and divided into the squares, 1, 2, 3...... 17 and 18 corresponding with the anemometer stations. A slot, *a b*, was made in the top cover, B C, of the adjutage, and closed by a wooden slide, moving with easy friction in a guide screwed to the cover, the minimum travel being equal to double the width, B C, of the adjutage. In the movement from left to right or from right to left given by hand to this slide, its extreme positions will be M N and M′ N′, the mean position being M″ N″; and at no point of its travel can there be penetration of the outer air into the inside by the slot *a b*, which is constantly covered by the moving slide.

As shown in fig. 3, the anemometer being hung from the end of a small but rigid rod, of such a length that if one

of its ends occupies point 1 (see fig. 2) in the upper tablet the other will occupy station No. 1 of the adjutage, it will penetrate into the interior through a hole in the slide. If the slide is at rest all that will be required is to lower in a vertical direction the upper end of the rod, bringing it in succession opposite stations 1, 6, 7, 12, 13 and 18 of the tablet, for the centre of the anemometer to occupy the corresponding stations; and if the instrument is to be displaced horizontally it will be sufficient to move the slide in the proper direction by maintaining it at a station for a preconcerted space of time, after the manner of a pantagraph, although in this case there was no reduction or enlargement.

In order to permit of throwing the anemometer in and out of gear from a distance without entering the chamber, it was hung from the end of a light but rigid copper tube; and a copper wire inside the tube was held by one of the experimenters standing on the adjutage opposite the numbered tablet, a spring fastened to the stand of the instrument acting through a small chain on the engaging lever to which the wire is attached on the side opposite the spring. When the wire is stretched the anemometer is thrown into gear, but at other times the spring, acting on the lever, throws the instrument out of gear, an arrangement that gave every satisfaction.

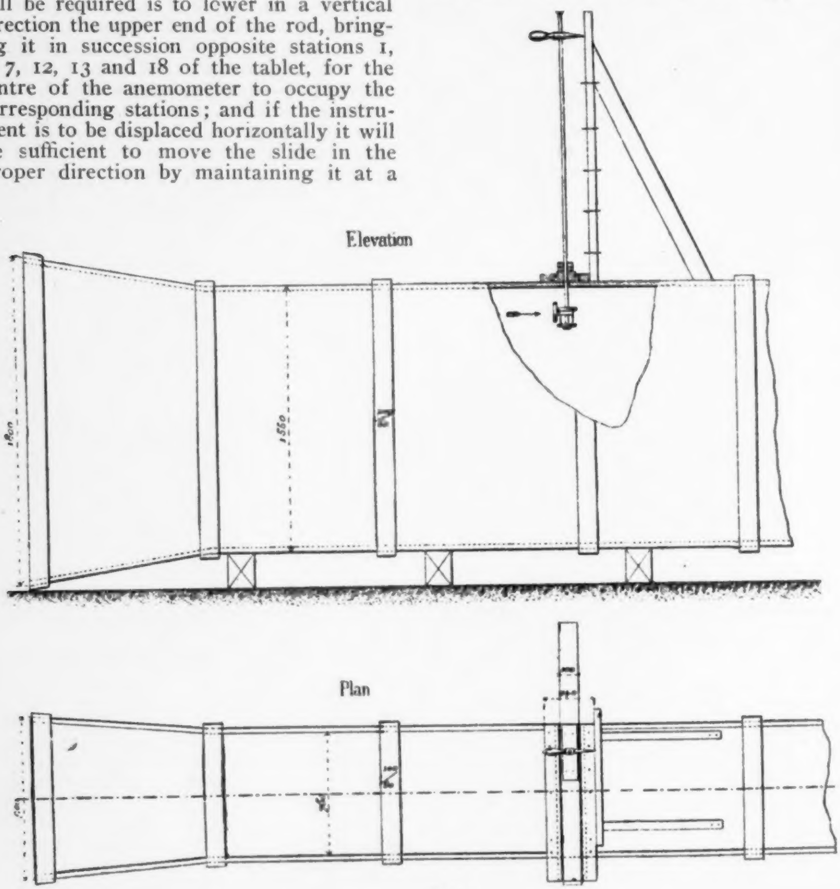


FIG. 3.

In 1897 each series of observations made on a given pipe was preceded by a gauging that comprised measurement of the speed at each of the eighteen stations marked on

the tablet, one minute being occupied at each. During this protracted gauging the fan's speed was kept perfectly constant; and, for taking into account slight variations in the engine speed, the fan revolutions were taken simultaneously with the gauging, the speeds observed being all reduced to a given fan speed supposed constant. The experiments following the first of each group only comprised a gauging for one minute each at three points in the sectional area; and the total number of revolutions made by the anemometer during this space of time was registered. In accordance with M. Murgue's remarks as to the constant ratio between the mean speed of the air-current for the whole of the sectional area and its speed at three given points, the result was arrived at by a simple proportion sum.

In 1898 this manner of making the observations was modified for the following reasons: The prolonged gauging before beginning each group of experiments took up too much time for recording so many observations as those required; but the chief reason consisted in the difficulty of keeping the fan at a constant speed, especially when setting up a comparatively high watergauge, the boiler though fired hard not being able to make sufficient steam.

There are, however, grounds for believing that the second method was quite as correct as the first. One permitted, which could not be obtained with the other, of tracing curves of equal speed; but this advantage was slight, because a knowledge of the distribution of the different speeds is only useful if it relates to the pipe experimented with, and the gauging was effected in an adjutage the sectional area of which was always far greater than that of the pipe. The time during which the anemometer was kept at each station has never been less than six seconds, which is considered sufficient by all who have taken up this question; and the rectangular form of the adjutage, 1.5 m. by 0.75 m. (4 ft. 11 in. by 2 ft. 5½ in.) lends itself readily to a division into equal squares, their centres corresponding with the stations.

Influence of Air Infiltrations.—However carefully the joints be made, it is difficult to entirely avoid the errors resulting from slight air infiltrations over the distance with respect to which the loss of load is to be measured; but for reducing this cause of error to a minimum the author made a point, before beginning each series of observations, of gauging the entrance and exit adjutages at the maximum fan speed, so as to better appreciate the extent of the leakage, although with metal pipes an almost entire concordance between the inlet and outlet volumes was attained.

TAKING THE WATER-GAUGE.

In all the observations made under the author's superintendence, the difference of the total pressure was measured by two Pitot tubes placed along the centre line, the pipe facing the air-current; and here began the difficulties. These tubes ought to have been placed at the points of the stations, up-stream and down-stream, where reigned the mean speed; but this was not done, for want of time, the tube being always held in the middle as if the total pressure were the same over the whole sectional area. The Murgue apparatus was set up, at the up-stream end, on one of the side faces of the air inlet; and a slight shelter protected the pressure-gauge arranged on the heavy cast-iron plate already mentioned. Indiarubber tubes from the cocks connected the pressure tubes above and below with the large and small flask of the gauge respectively. In the experiments on pipes of slight diameter these tubes were laid along their length entering at two points comprising between them the length to be observed; and the two tubes were bent to a right angle so as to constitute a Pitot tube.

Referring to fig. 4, in the observations on straight pipes, the tubes, T T′, starting from the Murgue pressure gauge, proceeded one to the up-stream station, A, and the other to the down-stream station, B, F being the fan and the arrow showing the direction of the current. In the observations on separate straight portions connected by various bends the tubes might be arranged so as to permit of measuring at will the total loss of load, as well as the partial loss of load in each portion of the pipe line; and it is thus that, in the case shown by fig. 5, the water-gauge may be taken if desired between the points 1 and 4 of the total distance traversed, or between the points 2 and 3 of the partial distance.

CONDUCT OF THE OPERATIONS.

The six observers were placed—the first near the exhaust fan for recording its speed; the second on the top cover of

the up-stream adjutage facing the tablet above mentioned, for moving (as has been described) the rod of the anemometer, which he threw in and out of gear from a distance; the third moved hori-

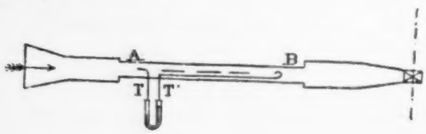


FIG. 4.

zontally, from left to right and from right to left, the slide covering the upper slot of this adjutage, and the fourth, holding a chronometer, gave the signals for beginning and finishing the observations, while the fifth and sixth respectively took the water-gauge and booked the number of revolutions made by the anemometer. The extreme stations, up-stream and down-stream, were connected by electric-bell apparatus, so that the signals agreed upon could be exchanged.

So soon as the fan acquired the determined speed, the down-stream observer notified those up-stream; and at a stroke from the bell the anemometer was released and moved about in the different stations, where it was kept for a given number of seconds signaled by the chronometer man; and during this time as many readings as possible (at least ten per minute) were taken of the depression. At the end of the observations the operators formed into two groups, each reading in turn the tachymeter and anemometer figures, this checking of the observations, strongly recommended by M. Murgue, being indispensable for avoiding errors.

GENERAL FORMULA EXPRESSING LOSS OF LOAD.

After describing the numerous experiments with both straight and curved pipes, carried out in the above-mentioned manner, and quoting Herr Althans' simple formula for expressing loss of load, the author states it as follows:

$$h = 0{\cdot}0007489 \times \frac{L}{D^{1\cdot373}} \delta^{\frac{2}{3}} v^2 \qquad (1)$$

h being the loss of load, L the length of pipe, D its diameter, δ the weight of a cubic metre of air, and v the mean speed of the fluid. He was able, thanks to the many and various observations made, to determine the true power which connects the loss of load with the mean speed, finding it equal to 1.916. As regards only the passage of air through pipes used for ventilating preparatory workings, a case which supposes for δ a value near upon 1.2 kilogr. (3 lb.), he feels justified in stating a = 1; and he was led empirically to modify the formula to the following:

$$h = 0{\cdot}000765 \times \frac{L}{D^{1\cdot506}} \delta\, v^{1\cdot916} \qquad (2)$$

A table is given (in the original paper) of the values calculated by formulæ (1) and (2) with the experimental results obtained for a whole series of diameters comprised between 0.259 and 1 metre; and a comparison of these values leads to the following

CONCLUSIONS.

1. For slight diameters the non-concordance between the calculated and observed results is sufficiently marked, and more so with the Althans formula (No. 1) than with that proposed by the author (No. 2).

2. For pipes rough inside, such as those of 0.45 m. (1 ft. 6 in.) and double that diameter, comparable with the state of a cast-iron surface, the Althans formula expresses the results observed with very slight divergence; but for smooth pipes

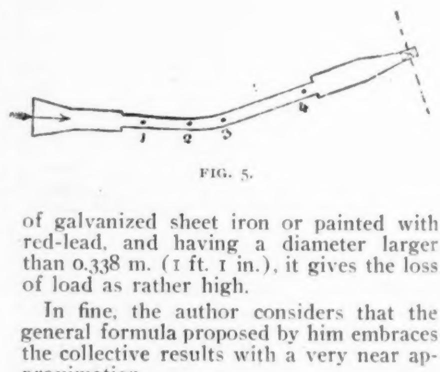


FIG. 5.

of galvanized sheet iron or painted with red-lead, and having a diameter larger than 0.338 m. (1 ft. 1 in.), it gives the loss of load as rather high.

In fine, the author considers that the general formula proposed by him embraces the collective results with a very near approximation.

Handling Water Ballast in Ships by Compressed Air.

Among the recently discovered uses for compressed air is that of handling the water ballast of ships. As is well known, modern vessels are provided with an inner water tight floor or bottom, usually placed four or five feet above the keel,

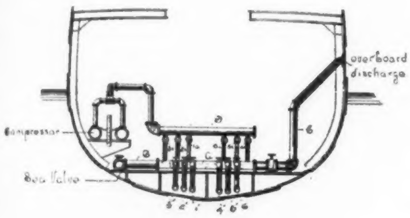


FIG. 1.

forming with the shell a double bottom which strengthens the vessel, and makes it safer against leaks.

The space between the bottoms is divided into a number of compartments into which water is flowed for use as ballast.

In order to trim ship it is necessary to vary the amount of water ballast or to shift it from one compartment to another. This has hitherto been done by means of ponderous ballast pumps attached to a reservoir or "header" and connected by pipes with the various tanks.

In Figures 1, 2 and 3 we illustrate a system of ballast handling that dispenses

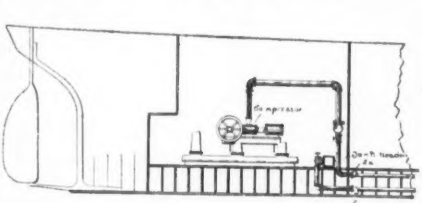


FIG 2.

with the pumps and controls the ballast entirely by compressed air. This system is the pioneer of its kind and is described in a patent issued Nov. 20, 1900, to Geo. B. Willcox, of Bay City, Mich. The system consists in omitting the ordinary ballast pump by which the water ballast is usually controlled, and using an air compressor to force air into the tank to be emptied, thus displacing the water, which flows out into the water header and thence either into another tank or overboard, as desired.

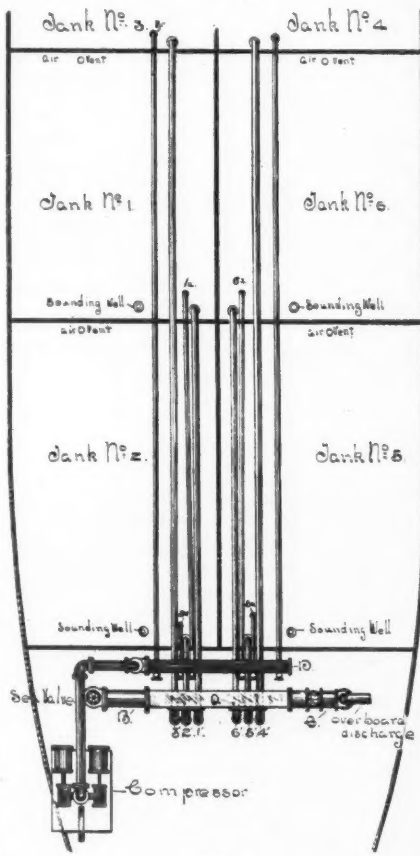


FIG 3.

A compressed air reservoir or header similar to the water ballast header is provided, and each tank is connected to the air header by means of an air pipe. Suitable valves permit the discharge of air into the tanks in any desired combination. Owing to the high velocity of the

air a large volume of water can be displaced by means of a small air pipe.

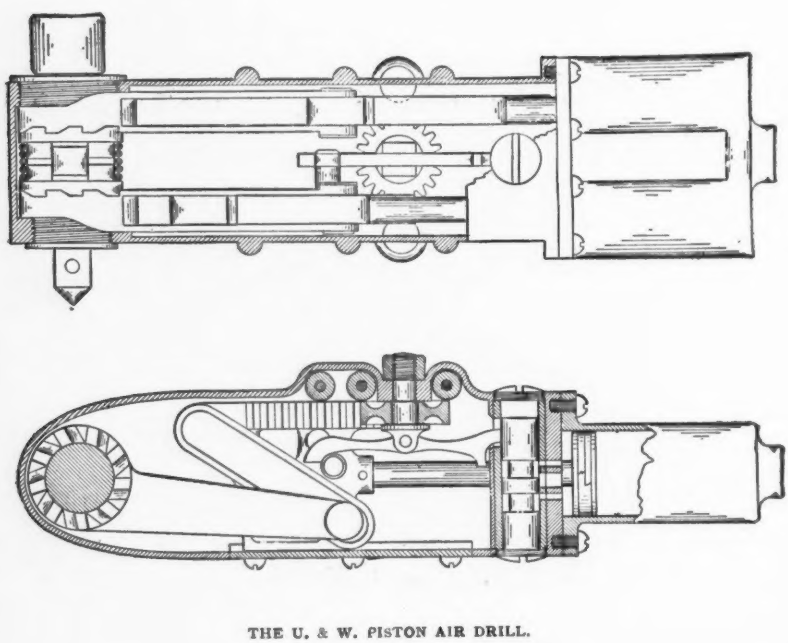
The advantages of this system are that the water ballast can be shifted at will from one tank to another without pumping any water overboard and without taking in harbor water. The location of the air compressor is not confined to the line of the discharge pipe as ballast pumps must be. With this system the ballast water does not pass through pump valves, but has a free flow and the frictional resistance of valves and the danger of blocking them by refuse is eliminated. An air compressor is very much lighter for a given capacity than the ordinary ballast pump, and will work with about ten times the economy of the ballast pump, besides being available for operating deck hoists, capstans, ash hoists, repair tools, etc., when it is not being used for handling the water ballast. This system is the subject of the first patent ever granted for a pneumatic ballast handling system, and will doubtless soon come into general use.

The U. & W. Piston Air Drill.

The accompanying cut shows the detail construction of the U. & W. Piston Air Drill, manufactured by the Columbus Pneumatic Tool Co. of Columbus, Ohio.

The drill being of an entirely different design from any other machine of this class, and embodying some novel and practical ideas, the following explanation will prove of interest to our readers.

This machine is of the double piston type, both pistons working through the medium of arms and crossheads upon a single shaft; turning it with the power derived from both cylinders. In order to affect this concentration of power, a gear is placed between the crossheads, working in racks cut at the base of each. The successive strokes of the crossheads move the ends of the arms up and down. The other ends of these arms encircle the shaft and engage lugs on it, thus revolving the shaft. The teeth of the arms and clutches never engage except on the for-



THE U. & W. PISTON AIR DRILL.

ward stroke, or at the time of the upward movement of the end of the arm. As air enters the cylinders at the end of each stroke, it will be seen that the gear referred to above is of great importance, inasmuch as it is the medium of transmission of the power developed in the return stroke to the side on the forward or working stroke.

Two valves and a shifter distribute the air. The auxiliary valve is set by the shifter in its movement up and down, and the main valve is set by air properly admitted by the auxiliary.

The points of superiority claimed for this tool are: durability, capacity for doing work in close quarters, strength, lightness and the absence of the necessity of frequent oiling.

The Krause Air Filter.

A novel apparatus in the shape of an Air Filter has recently been patented and placed on the market by Mr. Arthur E. Krause, of 345 Fairmount Avenue, Jersey City, N. J.

The object of an Air Filter is to prevent dust, grit, ashes, etc., and any impurities from entering the intake in Air Compressors, Air Pumps, Blowers, and, in fact, all machinery handling air, and in which grit or impurities are detrimental not only to the operation of the machine itself, but also to the operation of such other machinery depending upon the first.

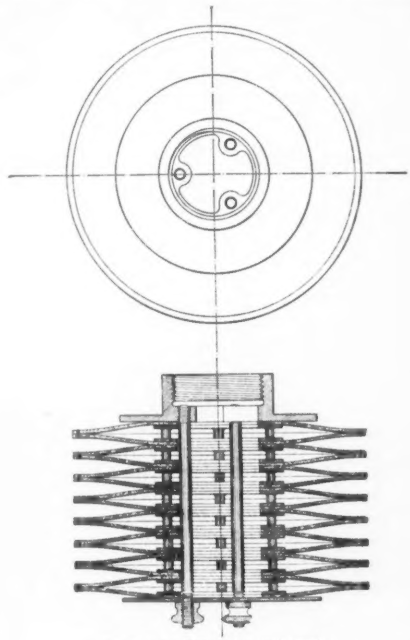
Air filters have been tried at different times, but have been discarded on account of the great amount of space taken in order to obtain adequate filtering surfaces, and also for the reason that the intake pressure was considerably reduced below the atmosphere.

Mr. Krause's Filter, which we illustrate herewith, is very simple and takes very little space. For instance, a filter suitable for a 1½" intake pipe would be only 6" dia. by 5" long, and such a filter can be attached to intake pipes for Air Pumps, Air Compressors, Blowers, Gas Engines, etc.

The construction of the filter is as follows: Circular shaped flat bags made of felt, cotton, asbestos, or any other suitable material, with thin outer edges sewed together and having a concentric opening so as to obtain access to the interior of the bag from both sides.

Into the interor of each bag there are inserted two flat ring-shaped washers made of sheet metal, one of these washers having protruding bosses stamped thereon, the other washer is perfectly plain.

When placed within the bags the bosses of one washer are placed against the flat side of the other washer, thus making a separating space between the two washers, which serves as a free passage for any air filtered into the bag from the outside. After the washers are thus inserted within the bags, a certain number of them are placed over the above-mentioned tierods,



THE KRAUSE AIR FILTER.

the number of bags depending upon the length of the supports and amount of filtering surface desired.

After all of the bags are thus placed over the supports, a metal washer, or disc, having three holes corresponding to the position of the three supports, is placed over the bags, and the thumb nuts are screwed up against the disc, thus forcing the separate bags together at the edges of the central openings, so that perfectly tight joints are secured.

There is no pressure exerted on any part of the surfaces of the bags, so that the air has perfectly free access to such

surfaces, and after filtering through the bags from the outside, the air passes through the free space between the inside washers and into the interior of the body of the filter, from whence it is drawn off by the air pump or compressor entirely freed from dust or grit.

It will be readily understood that this arrangement of the filtering bags will permit of a very extensive filtering surface within a very small space, at the same time allowing ample air spaces between the bags to render all of such surface effective and efficient.

These filters can be cleaned or dusted while the machinery to which they are attached is in operation, or a new set of bags can be inserted in a few minutes' time.

To show the great amount of filtering surface which can be obtained in a very small space we want to say that a 1½" filter, as constructed, would consist of 22 bags, each bag having on each side a surface of 15 sq. inches, making the total filtering surface 660 sq. inches, and the space occupied by same does not exceed ⅛ of a cubic foot. Thus it will be seen that a filter covering one cubic foot in volume could have a filtering surface of 36 sq. ft.

Of course the filtering surface depends not only upon the size pipe or opening, but also upon the quantity of air to be filtered, and upon the amount of dust or grit which may be contained in the air.

Owing to the large air filtering surface the resistance to the inflow of air is hardly appreciable if the filter is dusted occasionally.

Dont's ! For Users of Compressed Air.

The following hints have been drawn up in a somewhat breezy American style:

Don't install a compressor just about equal in capacity to your present requirements, for when once you have compressed air available its number of uses becomes legion. Good practice is to provide a compressor at least fifty per cent. greater in capacity than your immediate necessities demand. Duplex compressors are made devisible, permiting the installation and operation of one-half at first and the other half later, when the additional capacity is needed.

Don't accept the theoretical capacity of an air compressor, stated in the list of the maker, as the equivalent of the actual volume of air needed for your service. Remembering the difference between theory and practice, allow a small deduction for friction, heat, clearance, etc., being unavoidable losses in air compression, before calculating what your actual delivery in compressed air will be.

Don't buy an air compressor because it is cheap. It will prove the most expensive proposition of its size that you have ever encountered. If a water pump fails in its work, you will know it at once; if a steam engine is deficient, its shortcomings are self evident; but if an air compressor is poorly designed or badly constructed, it may continue in the evil of its ways until the scrap heap claims it for its own, unless, as is more than likely, an absolute breakdown calls attention to its deficiencies, and you learn all too late that the hole it has made in your coal pile, added to the loss of keeping it in repair, would have paid a handsome interest on the additional first cost of a properly-designed and properly constructed compressor.

Don't buy a second-hand compressor unless you know it has given satisfaction in work similar to your own, and that its working parts retain their full measure of usefulness without deterioration. An air compressor with valves, pistons, etc., worn out or in bad repair can waste more good power than anything of its size known.

Don't buy a compressor that your neighbor used for operating oil burners because you intend putting in pneumatic tools. For, even if all compressors look alike to you, experience teaches that oil burners operate under 12 pounds pressure, whilst pneumatic tools require 100 pounds, and the oil-burner compressor, with unevenly proportioned cylinders, devoid of water jackets, will equal your service as well as a low-pressure boiler for heating will run a high-speed engine.

Don't use air-break pumps or direct-acting compressors. Statistics show that their steam consumption is about five times that of a crank and fly-wheel compressor for the same volume and pressure of air delivered.

Don't install a steam-driven compressor if your steam supply is short and plenty of belt-power available.

Don't put in a belt-driven compressor if you have plenty of steam and are short of belt power.

Don't purchase a compressor of out-of-date design because you have heard of it for many years. Noah set the fashion in arks, and is known throughout civilization, but modern house-boats have evidenced the progress of the times by departing materially from Noah's standard.

Don't draw your intake air to the compressor from a hot engine-room, or from any point where dust is abundant. The volume of air delivered by the compressor increases proportionately as the temperature of the intake air is lowered, and dust or grit entering the compressor clogs the valves, cuts the cylinders, and generally impairs the efficiency.

Don't use any old thing for an air receiver. Compressed air under 100 lbs. pressure will leak a horse-power through a 1-16 diameter hole in five minutes, and a well-made, strong and tight air receiver is the second essentially important factor if you would realize to the utmost all the advantages which compressed air provides.

Don't connect your air admission and discharge pipes improperly at the receiver. To secure the best results and eliminate moisture from the compressed air, connect your pipe leading from the compressor at the top of the receiver and lead your air pipe to points of consumption from the bottom of the receiver.

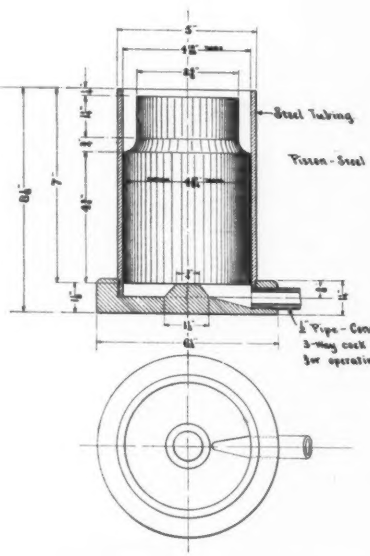
Don't have leaky air pipes. Test your piping when it is installed and at regular intervals thereafter, allowing the full pressure to remain an adequate length of time, and if the gauge indicates leakage locate and remedy it.

Don't install your piping without properly providing for drainage of condensed moisture at regular intervals in the system. The simplest method is to slightly incline the branches leading from the main line and insert drain cocks just before the hose connection is reached.—New Zealand Mining and Engineering Journal.

Air Gun.

As a great deal of trouble has always been experienced in driving out engine frame bolts, cylinder and saddle bolts on locomotives, the use of a cannon many times being brought into play, the Pennsylvania Railroad system has adopted what is known as an air gun for doing this work.

Figure one shows a section of the gun as they make it. It is nothing but a piece



AIR GUN

FIG. I.

of bored-out steel tubing screwed into a cap, which acts as a base. The size of the gun can be varied to suit different kinds of work, the diameter, length of piston and length of stroke being increased if more power is to be obtained. The three-way cock is attached to the air inlet so that after the air has shot up the piston, the air in gun can escape to the atmosphere when the three-way cock is turned.

Figure two shows part of an engine frame with several of the air guns in place for driving out the bolts. The three-way cock on the air inlet is opened and closed hitting the bolt with a sharp, quick blow.

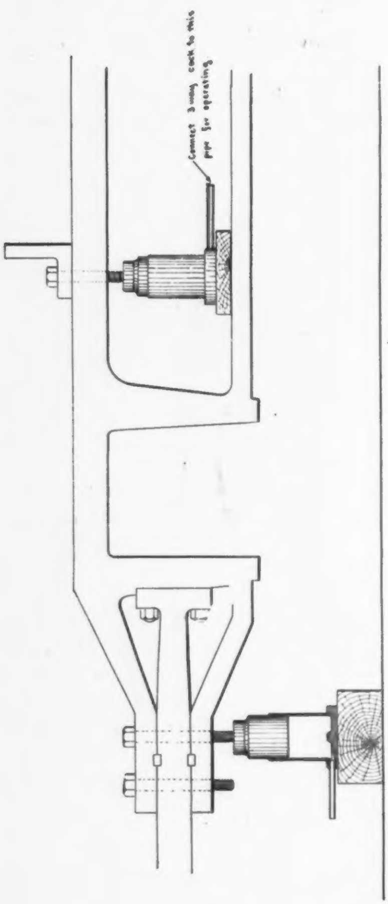


FIG. 2.

As shown in cut, the gun is blocked up intermittently, acting as a heavy hammer with wood to the required height for operating, which allows it to accommodate itself to many varieties of work.

Notes.

Compressed air is supplementing the mule in the mines of Wisconsin.

Messrs. M. R. Muckle, Jr., & Co., the Philadelphia representatives of Messrs. Westinghouse, Church, Kerr & Co., have removed to their new office, No. 512 Stephen Girard Building, No. 21 South 12th Street, Philadelphia, Pa.

A patent has been taken out by Mr. A. Koehler, of Hamburg, for an apparatus which burns liquid fuel and disperses it by means of air under high pressure, instead of by a steam jet. A non-illuminating flame of great heating power is produced.

A London plumber has arranged a new system of burglar alarm by means of compressed air. When the modern Bill Sikes opens a window or a door the compressed air blows a policeman's whistle and lights an electric lamp to act as a guide, so that the man in blue shall know where he is wanted.

The Postmaster-General has appointed a committee of experts to consider matters relating to the use of pneumatic tubes for the transmission of mail. The members of the committee are: Theodore C. Search, Philadelphia; R. H. Thurston, Ithaca, N. Y.; S. C. Mead, New York; Lyman E. Cooley, Chicago; Alfred B. Fry, New York; William T. Manning, Baltimore, and Frederick A. Halsey, New York.

George B. Carpenter & Co., whose plant was burned out a few months ago, have remodeled their building at Fifth avenue and South Water street, Chicago, with an entirely new boiler plant, and a complete system of heating, ventilating and pneumatic tube service. They are manufacturers of tents, awnings, railway supplies, shipping supplies and general contractors' material. They took possession of the new building on December 1.

Salaried Positions for Learners is the title of a pamphlet issued by The Inter-

national Correspondence Schools, Scranton, Pa. It tells how a young man can become a mechanical or electrical engineer or architect and support himself while learning. It contains photographs of a score or more students who have obtained better positions as a result of their studies, and some specimen drawing plates showing the remarkable progress made by students.

The G. P. McGann Air Brake Company of Detroit, Mich., in addition to a handsomely decorated booth at the annual convention of the American Street Railway Association, were enabled, through the courtesy of the Kansas City-Leavenworth Railway, to take many delegates interested in their brake over the road, and afford them an opportunity to inspect the working of this brake, which has been in use on this road for the past year.

Articles of incorporation were filed with the County Clerk here to-day of the American Pneumatic Carpet Company. The company is capitalized at $500,000, of which $3,000 is paid in. The object of the concern as stated in the papers is to establish, build, construct, repair, maintain, and operate plants for the purpose of cleaning carpets by compressed air and other processes. The incorporators are: A. D. Easton, Z. B. Mead and S. G. Mead, all of East Orange.

A petroleum spray is used on the Missouri Pacific Line for lighting the fires of locomotives. The reservoir for the oil is mounted on wheels. Compressed air is used to spray the oil. The air can be taken from any Westinghouse receiver or pump. In using the apparatus, the bed of coal is first placed on the grate, and then the jet spray is ignited and directed on to the coal, being moved over the surface until the whole is ignited, which usually requires about 15 minutes.

On the Erie canal, at Lockport, N. Y., a pneumatic balance lock is being substituted for a flight of old-fashioned stone locks. The new lock consists of two steel chambers, one for ascending and the other for descending boats. Each chamber is divided into two parts, an upper one containing water to receive the boats and a lower one containing compressed air on which the upper chamber floats. When a boat has been run into the upper chamber it is either lowered or raised, as may be desired, by filling or exhausting the air chamber beneath it.

The Board of Directors of the Compressed Air Company met last week at the offices of the company, No. 621 Broadway, New York. Among those in attendance were Thomas Dolan, William L. Elkins, Henry D. Cooke, General C. H. T. Collis, Newell C. Knight, William H. Kimball and General G. E. P. Howard. The equipment of another cross-town line with compressed air was discussed. Three sub-companies are in organization to introduce air cars in Ohio, Missouri and New England. The board passed a resolution authorizing the listing of the stock of the company on the New York Stock Exchange.

The New York Central is figuring on adopting compressed air motive power in the tunnel leading from the Grand Central Station to Harlem. Owing to the smoke and dirt which result from the use of coal-burning locomotives Président Callaway has had under advisement the matter of compressed air as a motive power. In this connection Henry D. Cooke, president of the Compressed Air Company, said yesterday: "It is true that their engineering department was preparing plans for an air locomotive capable of hauling a standard New York Central train, including the steam locomotive, from Forty-second street to Mott Haven."

Another step in the construction of explosive engines is embodied in the Banke motor. In this the mixture of hydrocarbon vapor and air is drawn into the cylinder as usual but is mingled with a fine spray of water. The advantage is twofold. When the mixture is compressed the water absorbs much of the heat of compression, thus preventing over heating and pre-ignition. On exploding a good proportion of the heat is used in evaporating the water and is later recovered in the shape of useful work done by the exploding steam. A test recently made on a 20-horse-power benzine motor showed a thermal efficiency of 28 per cent.

Albanus L. Smith & Co., of 1305 Arch street, Philadelphia agents for Pennsylvania for the United Flexible Metallic

Tubing Co., Ltd., of England, offer the product of this company as a substitute for rubber hose. It is offered for a variety of service—for conducting steam, compressed air, water, oils, gas and acids. The first cost is greater than that of rubber hose, but the life of flexible metallic tubing is longer. It is manufactured in sizes from ¼ inch up to 8 inches internal diameter and to stand 100 to 200 pounds steam working pressure, or on special orders up to 1,500 pounds. It has been on the market in Europe for five years, and 2,000,000 feet are in use abroad.

Erie officials are arranging for the erection of a plant for the storage of compressed air for the air brake freight cars. A stationary engine will pump air into a storage reservoir and pipes will be laid from it to all parts of the yard, and the air brakes of an incoming train can be attached to any of them and tested, and trains can also immediately be supplied with air from the plant. This will abolish the delay caused by a locomotive pumping air into the piping of the brake before the train can leave the yard. Later on new machinery will be placed in some of the shops there and heavy weights will be lifted by compressed air from the same plant.

A general meeting of the members of the North of England Institute of Mining and Mechanical Engineers was held in the Wood Memorial Hall, Newcastle-on-Tyne, on Saturday, October 13, under the presidency of Mr. J. G. Weeks.

Mr. H. Humphris submitted a short paper on a new rock drill, which was exhibited and described. The method of working was described as follows:—In the first place a hole was drilled, round, 1⅛ inch diameter, then the drill followed making a double < > shape. With the drill not only slate rock was saved, but less powder was used owing to the two weak points made with the drill < > as the line of split would follow the two weak points. The drill would do the same thing on any stone, splitting it as required. He intended to improve the drill and make it more useful for any kind of rock or stone.

President Cooke, of the Compressed Air Company, states that the company have concluded negotiations which will result in their acquiring the Rome Locomotive and Machine Works, and it is their intention to erect additional machinery and additional shops, and to put in a thoroughly up-to-date plant and management, in order to supply the daily increasing demand for air motors. After careful consideration by this company and the approval of its engineer, Robert Hardie, John L. Stagg, a man of large mechanical experience, has been selected general manager for the works. He has orders to immediately proceed with the manufacture of motors to the limit of the present plant, and to increase the output at the earliest day to the fullest possible extent. Additional motors are now needed for service in Newport, Buffalo, St. Louis, Massachusetts and Ohio.

The installation of small hoists suitable for serving machine tools when the work handled is generally too large for one man to put in place, is one of the improvements in the modern machine shop which has worked much benefit and saved much time. When the work to be lifted varies in weight from 75 to 500 pounds, it is believed that the pneumatic hoist is generally best for the purpose. To be of most service it should always be available; therefore, one hoist can serve only a small number of machines at most. This being the case, there is no objection to having it attached to the feeder pipe line by a hose of only sufficient length to allow it to reach the machines lying in its field of operation. The cheapness and simplicity of the pneumatic hoist, as compared with the electric or any other form suitable for the purpose are so strongly in its favor that it seems to have no competitor in this particular field. The air compressor for serving such a hoist is probably best electrically driven when of not too great capacity, but if the size must be large, a steam compressor forming a unit in itself seems best, it being assumed that water-power is not available.

The importance of liquid air has been so greatly exaggerated that it has been difficult to form a fair estimate of its merits. In a paper to the German Society of Naturalists, Dr. Carl Linde has shown that it has three properties of possible industrial use—its low temperature, its adaptability for converting heat energy into mechanical work, and its separation into varying mixtures of nitrogen and oxygen

by fractional distillation. The cost of liquid air cooling—which is theoretically 17 times greater than refrigeration by ordinary machines and practically about 40 times greater—must prevent its use except for very low temperatures, or in the rare cases where cost is of secondary importance. For driving motors, liquid air has small efficiency as compared with water, and the cost must limit its use to a few special purposes, like torpedoes and submarine boats. Mixed with petroleum, however, it may give a powerful internal combustion motor of small weight by ensuring perfect combustion in the cylinder. Liquid air as an explosive has not given encouraging results. As the gas first evaporating from liquid air is nitrogen, it is possible to concentrate the oxygen in the mixture to 50 per cent. or more, and this may prove of much value, especially as it can be made inexpensive by utilizing the cold of evaporation to aid in freezing more air.

19421 (1899). Improvements in Rock Drills and the Like.—W. D. Jones, Brunditt's Granite Quarries, W. O. Pierce, 12, Crimea-terrace, both of Penmaenmawr, North Wales, and W. M. Treglown, 114a, Queen Victoria street, London.—Refers to rock drills and like tools in which the cutting is effected by a succession of blows on the head of the cutting tool, the motive power supplied by steam, or water or air under pressure. The cutting tool needs to be rotated when in use and this has hitherto been done by the hand of the operator. In this invention the rotating device turns the tool automatically, and thus greatly increases the efficiency of the drill. The rotating device can be operated by the exhaust from the drill or direct from the power supply. In carrying out the invention, a strong metal sleeve is placed over the lower end of the barrel of the drill, and beyond this sleeve is attached to the barrel a small motor of any suitable kind to which the power is conveyed. Attached to this motor are geared wheels which drive a worm placed transverse to the drill barrel. This worm engages with teeth on the sleeve and causes it to rotate, and thereby turn automatically the socket or tool holder and the tool itself. In order to give a jumping movement to the tool as it rotates, two spring pawls are attached to the said sleeve and cause them to engage with two lugs on the mouth of the tool holder.

The Philadelphia Pneumatic Tool Co., Stephen Girard Bldg., Philadelphia, Pa., reports a large increase in business for the month of November over the preceding months.

Their Pneumatic Hammers are establishing for themselves a very enviable reputation as evidenced by the duplicate orders received from some of the largest manufacturing concerns in the United States.

Recent improvements in their Long Stroke Riveting Hammer have given very satisfactory results, and they report a large number of orders booked ahead. In one day in November they shipped eleven of these Long Stroke Hammers besides the shipment of other tools.

The use of compressed air for foundry work has been largely increased by the Sand Rammers recently put upon the market by this company, not only as a labor-saving device, but in doing better and more uniform work. A large number of these tools have been sold and have met with flattering success, as shown by the increasing number of orders being received.

This company states that owing to its inability to fill orders, they are making arrangements to further increase their capacity, and shall, in the near future, be able to fill all orders promptly.

Mr. Robert T. Mickle, M. E., formerly with the Kensington Engine Works, Ltd., Philadelphia, Pa., has been elected Vice-President of the company to fill the vacancy caused by the resignation of Mr. Geo. W. Borton.

It was about a year ago that liquid air as a motive power and explosive, a means for driving automobiles and all other kinds of machinery and motors, and particularly and especially as a method for extracting the dollars from the pockets of the unwary, loomed far to the front, and held, as it were, the centre of the stage in popular estimation.

To-day, in order to find liquid-air literature, says the Electrical Review, of New York, one must turn back to the files of the newspapers which boomed its merits in their advertising columns, or of the technical journals which exposed its fallacies, or the waste baskets of yore which contain the circulars sent out by enthusiastic promoters. Glittering and alluring were the promises, large and important

the results, financial and otherwise, that were promised. But where is the realization, and what has become of the money that was spent in the liquid air boom?

This remarkable substance, which was about to displace electricity, and all the other agencies for power generation and many other things, has gone back to the shelter of the laboratory to emerge no more, we hope, except as an interesting product of modern scientific means and a valuable accessory for certain physical researches. About three or four times a decade the public seem to require some outlet for their financial enthusiasm and some subject around which their imagination may crystallize. We have had the Keeley motor, the electrical sugar refining scheme, the Reverend Brother Jernigan's scheme for extracting gold from sea-water and liquid air.

Dr. R. H. Thurston makes some strong remarks in writing of the proposed application of compressed air to automobiles. It stores comparatively little energy, is enormously costly, especially as a competitor with energy-storage fluids of little or no cost, requires very large quantities per horse-power delivered, and no known way exists for its storage for any considerable or satisfactory period without immense waste.

According to Linde—perhaps its most successful, experienced, and reliable producer—it requires 100-horse-power at the compressor to produce as many pounds per hour, and it can develop but a fraction, probably a small fraction, of that amount of power in regasifying. It loses by simple vaporization, even in large vessels, 10 gallons and upwards, about 4 per cent., under the most favorable conditions for its preservation, each hour. Its efficiency in the motor is found to be about 4 per cent.; that of the steam engine is from 7 to 20 and more, and that of the gas engine ranges to still higher figures.

In the perfect heat engine the quantity of air required to do the same work within the same range of temperature of operation is about 16 times as much as of steam; while steam costs nothing as a crude material, and liquid air costs no one knows precisely what—probably not less than three or four times, perhaps 10 or 15 times, as much as the fuel used with steam engine or the gas engine. The wild claims of the promoter of the stock companies now in the market for speculative purposes are probably based on but little better reason than those of Keeley or of other mountebanks.

Taking its cost in the engine at the advertised minimum, about 8dols. per ton, and that of steam in the engine at about 0.00025dols. per pound, about 50 cents a ton, and 4dols. for coal, the relation is 16 to 1 in favor of steam per pound, and many times this per horse-power developed. A first-class steamship of 10,000-horse-power would probably pay 100,-000dols. for the air alone to operate the proposed system of machinery in a single voyage across the Atlantic.

The first compressed air locomotive for Iona Island, N. Y., to furnish motive power for cars containing ammunition, under contract with the United States Government, has been completed at the H. K. Porter locomotive works here. The new engine, with all its appliances and the charging plant necessary to its operation, will be shipped during the coming week. It is the type of locomotive decided upon for moving railroad cars about the vast magazines which are the store houses for ammunition used in the coast defenses and forts throughout the country. The engine now finished is a novel one, and was ordered, together with a complete plant for charging and operating, last summer.

It was stated at the shops yesterday that in event of the new locomotive proving a success and standing the tests that it will be put to, the Government will order a number of others like it, all to be used on the same island. Iona Island is probably the greatest store house for explosives that is owned by the United States. It is situated in the Hudson river, a short distance from New York, and from it ordnance and ammunition are sent out to the various points along the coast. For a long time the handling of explosives has been done with mules, dragging cars and carts. It has been a slow and tedious process, as well as a costly one. The island is covered with a series of railroad tracks, and cars from the West Shore railroad are used in shipping material, being loaded and moved about by teams. It is absolutely necessary that there should be no fire of any kind near the store houses of the ammunition. The success that attended the use of compressed air

locomotives in the great plant of the California Powder Company, near San Francisco, drew the attention of the army officials to the availability of compressed air machines for Iona Island, and after much planning the first plant was ordered. This consists of one locomotive capable of handling standard railroad cars, a series of charging stations along the lines of the rails for charging the locomotives whenever it is necessary, and a complete power plant for operating the compressors.

The new locomotive is said to be one of the largest of its kind ever built. It will run several miles without being recharged, and can be charged with air at any one of the numerous stations in less than 30 seconds. There being no fire of any kind about the locomotives, there is not the least danger from explosion.

U.S. PATENTS GRANTED NOV., 1900

Specially prepared for COMPRESSED AIR.

661,075.—AIR-BRAKE SYSTEM. John R. Richardson, Scranton, Pa., assignor of two-fifths to John F. Thomas, same place. Filed Aug. 16, 1900. Serial No. 27,046.

661,111.—AIR-BRAKE. John Shourek, Pittsburg, Pa. Filed Nov. 20, 1899. Serial No. 737,712.

661,184.—AMMONIA-COMPRESSOR. James T. Ludlow, San Francisco, Cal., assignor to the Vulcan Iron Works, same place. Filed Oct. 31, 1898. Serial No. 695,097.

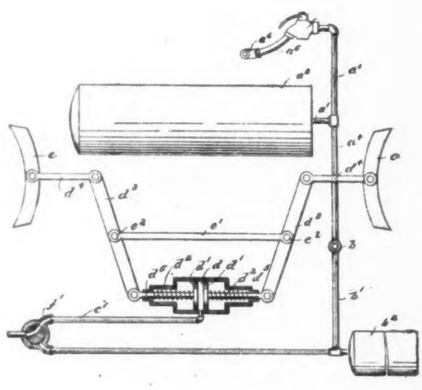
661,474.—AIR-BRAKE VALVE MECHANISM. Leopold Krimmelbein, Baltimore, Md., assignor of one-third to John F. Feldmann, same place. Filed June 27, 1900. Serial No. 21,717.

661,572.—AIR-BRAKE MECHANISM FOR CARS. Dennis Beemer, Detroit, Mich. Filed Feb. 25, 1898. Renewed April 30, 1900. Serial No. 14,916.

661,574.—QUICK-RELEASING VALVE FOR AIR BRAKES. Perry H. Corbett, Hannibal, Mo. Filed Aug. 7, 1900. Serial No. 26,196.

661,584.—STORAGE AIR-BRAKE SYSTEM. William K. Omick, Pontiac, Mich., assignor to the G. P. Magann Air Brake Company, Detroit, Mich. Filed July 3, 1899. Serial No. 722,637.

In a storage air-brake system, the combination, with a main reservoir and a coupling device associated therewith for connecting the main reservoir with a source of air supply, of an auxiliary reservoir connected with the main reservoir, a reducing valve interposed between the same, an air-brake cylinder, a pair of pistons therein yieldingly pressed toward each other, a pipe extending between the auxiliary reservoir and the air-brake cylinder at



a point between said pistons, suitable connections between said pistons and the brake-shoes and a manually-operated valve interposed in the pipe extending between said auxiliary reservoir and the brake-cylinder and adapted in one position to maintain the communication between the auxiliary reservoir and the air-brake cylinder and in the other position to seal the auxiliary reservoir and connect the air-brake cylinder with the atmosphere.

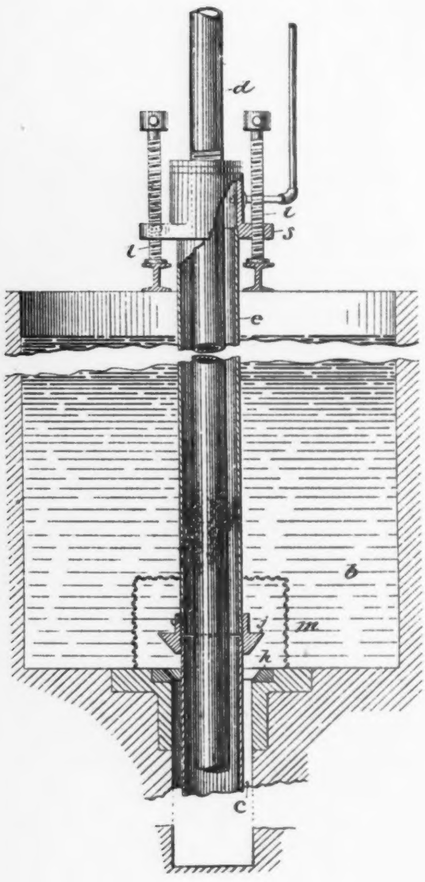
661,624.—APPARATUS FOR LIFTING WATER. Clifford Shaw, New York, N. Y. Original application filed March 22, 1900. Serial No. 9,696. Divided and this application filed May 29, 1900. Serial No. 18,395.

661,702.—AIR-BRAKE. John J. Nef, New York, N. Y. Filed June 22, 1898. Serial No. 684,159.

661,724.—AIR-DRAFT PROPELLING APPARATUS. Henry J. Newmarker, Edward J. Newmarker, and Benjamin C. Newmarker, Reno, Nev. Filed June 14, 1900. Serial No. 20,380.

661,623.—APPARATUS FOR LIFTING WATER. Clifford Shaw, New York, N. Y., assignor to the Bacon Air Lift Company, same place. Filed March 22, 1900. Serial No. 9,696.

In apparatus for raising water of the type embodying a submergence pit or well and air-lift mechanism, the combination of a valve-seat through which the water passes into said well or pit and through which the uptake and downtake pipes of said mechanism extend, one of them being within the other, and an annular valve encircling the outer of said pipes and adapted to be seated on said valve-seat.

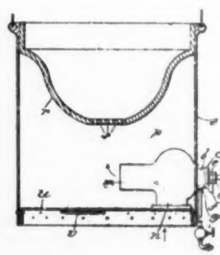


661,786.—PNEUMATIC HAMMER. Arthur C. Beckwith, East St. Louis, Ill., assignor, by mesne assignments, to the Western Railway Equipment Company, of Missouri. Filed Sept. 1, 1899. Serial No. 729,226.

661,860.—AIR MOTOR OR PUMP FOR AUTOMATIC MUSICAL INSTRUMENTS, ETC. Robert A. Gally, New York, N. Y. Filed Sept. 15, 1900. Serial No. 30,134.

661,950.—PNEUMATIC DEVICE APPLICABLE TO RIVET-HEATING FURNACES. Bert A. Brown, Bristol, Conn. Filed May 12, 1900. Serial No. 16,450.

In combination; the valve-cylinder containing the fluid-pressure inlet; the rotatable valve provided with plural valve-conduits and connecting jet-tubes adapted to be brought successively into connection with the source of fluid-pressure; and the conduit adapted to admit fluid or flowing material to contact and mixture with fluid flowing from a jet-tube.



662,054.—REPEATING AIR-RIFLE. William J. Burrow, Plymouth, Mich, assignor to the Daisy Manufacturing Company, same place. Filed Jan. 4, 1900. Serial No. 299.

662,055.—BURNER FOR PETROLEUM AND COMPRESSED AIR. Louis Charon and Frederic Manaut, Paris, France, Original application filed Nov. 9, 1899. Serial No. 736,419. Divided and this application filed May 15, 1900. Serial No. 16,747.

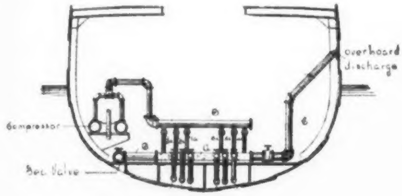
662,093.—AIR-VENT. Alfred Roesch, Bridgeport, Conn., assignor to the Davis & Roesch Temperature Controlling Company, of New Jersey. Filed May 9, 1898. Serial No. 680,105.

662,152.—AIR-BRAKE. William K. Omick, Pontiac, Mich., and George P. Magann, Toronto, Canada. Filed May 17, 1900. Serial No. 17,184.

662,189. — COMPRESSED - AIR ENGINE. Matthew Flood, Albany, N. Y. Filed Sept. 21, 1897. Serial No. 652,427.

662,208.—PNEUMATIC TIRE AND SHOE. Aaron Vreeland, Bloomfield, N. J. Filed June 6, 1900. Serial No. 19,335.

662,330. — MEANS FOR CONTROLLING WATER BALLAST IN SHIPS. George B. Wilcox, Bay City, Mich. Filed March 27, 1900. Serial No. 10,411.



The combination with water-ballast tanks having a common header and separate flow-regulating valves; of compressed-air conduits communicating with the several tanks; a common header or manifold for the several conduits; a source of compressed-air for forcing air into said manifold and conduits; and means, as valves in said conduits, for controlling the distribution of compressed air to said tanks.

662,574.—AIR CONVEYER. Eugene L. McGary, Pittsburg, Pa. Filed July 14, 1900. Serial No. 23,578.

662,601. — CARRIER FOR PNEUMATIC-DESPATCH-TUBE APPARATUS. Albert W. Pearsall, New York, N. Y., assignor to the Lamson Consolidated Store Service Company, Newark, N. J. Filed May 20, 1898. Serial No. 681,219.

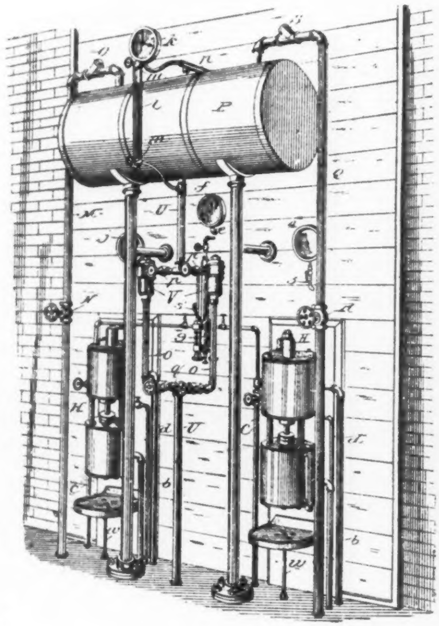
662, 675— PNEUMATIC TOOL. Herman Leineweber and George Leininger, Chicago, Ill. Filed March 30, 1900. Serial No. 10,789.

662,705. — PNEUMATIC VALVE-ACTION. Carl M. Welte, New York, N. Y. Filed April 12, 1900. Serial No. 12,558.

662,771. — PNEUMATIC CASH CARRIER TERMINAL. Frederick C. Cutting, Rochester, N. Y. Filed March 30, 1900. Serial No. 10,774.

662,838. — PNEUMATIC LUBRICATING SYSTEM. Elmer L. Vandresar and James L. Pilling, Chicago, Ill. Filed March 19, 1898. Serial No. 674,502.

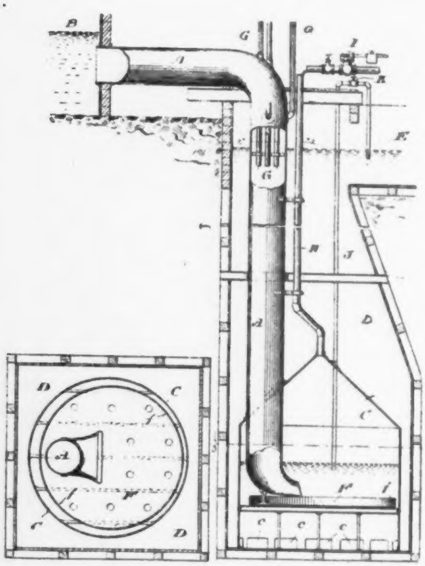
In a lubricating system the combination with a main filter, an oil-reservoir, a dispensing-tank, and a compressed-air re-



ceiver, of air and oil pipe connections between said filter, reservoir, dispensing-tank and receiver, a reduction-valve located in each of the air-pipes for controlling deliveries from said receiver, an oil-feed pipe leading from the dispensing-tank, oppositely-disposed branches in the latter running through secondary pressure-filters, a main oil-feed line, and an oil-return line, the latter discharging into the main filter aforesaid.

662,884.—HYDRAULIC AIR-COMPRESSOR. Fred C. Starke, Milwaukee, Wis., assignor of two-thirds to Claude L. Franklyn and John K. Russell, same place. Filed July 30, 1900. Serial No. 25,234.

In a hydraulic air-compressor the combination of a separating-chamber having a conical top and an outlet around the bottom, an ascending water-conduit into which said outlet opens, an air-delivery pipe leading out of the apex of said chamber, a spreading-table within said chamber above the outlet at the bottom thereof and a descending pipe having a water-intake and air-inlet at its upper end and a lateral discharge-opening at its lower end which projects at one side of said chamber over said table.



REISSUE.

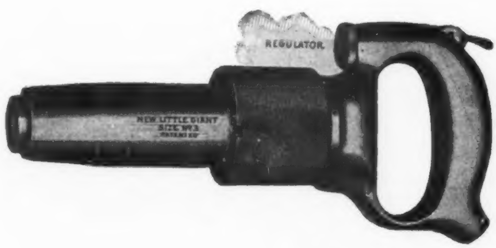
33,613. — AIR-CUSHION. Daniel Hogan, New York, N. Y., and Christian William Meinecke, Jersey City, N. J., assignors to Meinecke & Company, New York, N. Y. Filed Nov. 1, 1900. Serial No. 35,181. Term of patent 14 years.

"LITTLE GIANT"

PNEUMATIC TOOLS AND APPLIANCES

DURABLE EFFICIENT

DRILLS
BORING
MACHINES
BLOW-OFF
COCKS



HAMMERS
FLUE
ROLLING
MACHINES
RIVETERS

Light in weight and economical in use of air.

SENT ON TRIAL.

GUARANTEED AGAINST REPAIR FOR ONE YEAR.

STANDARD PNEUMATIC TOOL CO.

MANUFACTURERS OF

PNEUMATIC TOOLS AND APPLIANCES OF ALL KINDS.

NEW YORK, LONDON **MARQUETTE BLDG., CHICAGO, ILL., U. S. A.** PARIS, BERLIN, BRUSSELS.

LIKE A RAPID FIRE-GUN

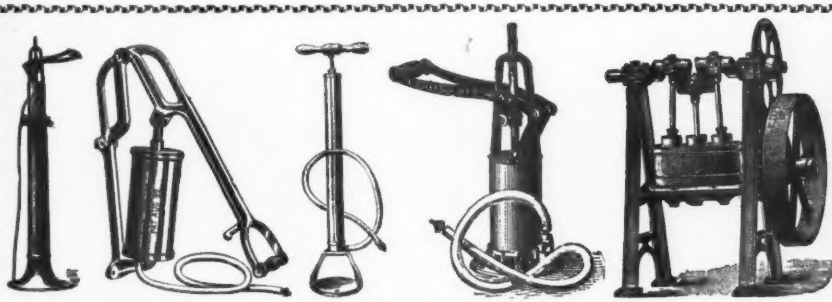
is the work of our Pneumatic Chipping and Riveting Hammers. They strike fifty blows while the hand-chipper or hand-riveter strikes one. This isn't merely saving—it's **Revolution.**

The defects of all other pneumatic hammers are overcome in ours by the Valve. It is perfect in principle and faultless in operation.

Send for Catalogue of our Pneumatic Tools, for Chipping, Riveting, Caulking, Drilling, etc.

PHILADELPHIA PNEUMATIC TOOL CO.

PHILADELPHIA. NEW YORK. PITTSBURGH. BOSTON.



COMPRESSED AIR PUMPS FOR ALL PURPOSES.

GLEASON-PETERS AIR PUMP CO., 20 West Houston Street, N. Y.

the
olor
st to
No
Cir-

CO.
S.A.

ds
OF
LS

co.

,,

S
le

"Embodying the Latest and Best Practice."

FOR ALL AIR USES

AIR COMPRESSORS.

SEND FOR CATALOGUE

NEW YORK AIR COMPRESSOR CO.

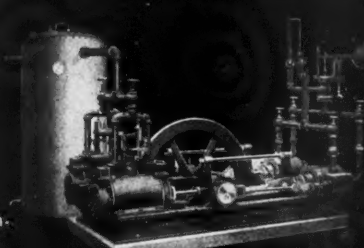
95 LIBERTY ST NEW YORK U.S.A.

"Fittingly Representative of an Age of Progress."

Air Compressors

For Operating
PNEUMATIC TOOLS,
HOISTS, ROCK DRILLS
and every other application of Compressed Air.

CLAYTON AIR LIFT SYSTEM
BREWERS AIR PUMPS



Clayton Steam Duplex Type.

CLAYTON AIR COMPRESSOR WORKS,

Catalogue.

26 CORTLANDT ST., NEW YORK.